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REPORT NO. CASD-NAS-75-004
CONTRACT NAS 2-8272

FUTURE PAYLOAD TECHNOLOGY REQUIREMENTS STUDY

FINAL REPORT

June 1975

GENERAL DYNAMICS
Convair Division

FOREWORD

The Future Payload Technology Requirements Study was conducted from June 1974 to January 1975 by Convair Division of General Dynamics with support from Rockwell International Space Division and General Electric Space Division. The Future Payload Technology Requirements Study team operated under the direction of the Systems Studies Division at the Ames Research Center headed by Alfred M. Worden. Larry R. Alton, in the Space Applications Branch of the ARC/SSD, was the Technical Monitor of the study. The study was funded by Code RX, Study and Analysis Office, NASA Headquarters, under the cognizance of Stanley R. Sadin. The study was under the guidance and review of the NASA/OAST Payload Technology Panel, Alfred M. Worden, Chairman. NASA HQ, NASA Centers and a large number of manufacturers/users provided significant advice, consultation, data, and critique in support of the task reported herein, as identified in the final report.

The results of this study effort are combined in two volumes, a summary report and a final report. The summary report volume contains an overview of study objectives, methods, and results. The final report volume, in addition, contains a detailed description of the technology requirements. These documents are identified as CASD-NAS-75-002 (summary report), and CASD-NAS-75-004 (final report).

ACKNOWLEDGEMENTS

Technical support for this technology study was provided by more than 200 individuals in the National Aeronautics and Space Administration and in the outside scientific and engineering community, who are listed in Appendixes A and B.

If one should attempt to identify the most important aspect of the NASA participation, it would be our discussions of the topics with them in their work and study areas during early and mid-study periods. The assistance in making these arrangements provided by members of the NASA-OAST payload technology panel was most helpful.

Later on in the study, the written critiques of the further defined technology requirement, by NASA as well as the manufacturer, research organization, and university personnel were most helpful in improving the credibility of this work.

We are indebted to all who gave time, talent, and energy to the work of the Future Payload Technology Requirements Study.

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SECTION 1

INTRODUCTION AND SUMMARY

The overall objective of the Future Payload Technology Study was the identification and description of technology items that must be advanced beyond the current state of the art in order for early shuttle-era NASA payloads to meet their currently defined objectives. The purpose has been to provide data that will effectively assist the NASA payload technology planning and budgeting effort. The payloads selected for this study were those included in the 1973 Payload Model, which NASA scheduled for delivery by the Space Transportation System in 1980s. Emphasis was on those payloads scheduled for flight in the early to mid 1980s.

1.1 SCOPE

The purview of the study team's activity consisted of the definition of technology advances needed for an overall mission model standpoint as well as those for individual payloads. The technology advances relate to the mission scientific equipment, spacecraft subsystems that functionally support this equipment, and other payload-related equipment, software, and environment necessary to meet broad program objectives.

In the interest of obtaining commonality of requirements, it appeared most useful to structure the study according to technology categories rather than in terms of individual payloads. The study was carried out within the classifications of the following categories:

- Collectors
- Sensors
- Generators
- Systems
- Special Devices
- Inertial/Electromechanical
- Life Sciences
- Contamination
- Structural and Spacecraft Mechanical
- Environmental Control
- Environmental Protection
- Cryogenic Control
- GN&C
- Propulsion
- Attitude Control/Measurement
- TT&C/Data
- Electrical Power
- Instrument Electronics
- Software

Some applications and desirable characteristics of equipment, particularly sensors, are in the classified literature as are some current state-of-the-art data. However, this study was restricted to the open literature and unclassified knowledge.

The team planned its activity to ascertain the best available and most credible information that will effectively assist the NASA technology effort in closing the gap between the current state of the art and the required state of the art for each item within the technology categories. For each of these items it was attempted to determine:

a. Advancement required based on payload objective.

b. Current state of the art as it relates to the advancement required.

c. Description of technology relating to the critical parameters.

d. Degree of benefit to the payloads.

e. Acceptable technology maturity, advancement, or confidence demonstration.

f. Potential problems, options, and alternatives.

g. Technology requirement schedule to support need date.

h. Expected advancement in the state of the art by the need date, if NASA expends no special effort beyond currently planned level on that specific technology item.

1.2 SUMMARY

1.2.1 STUDY APPROACH AND PARTICIPATING CONTRIBUTORS. The Future Payload Technology Requirements Study was performed in four steps extending over a period of eight months (Figure 1). The study began with an analysis of the NASA payloads for the 1980s to identify payload performance parameters and characteristics estimated to be beyond the current state of the art. These requirements were identified primarily by analysis of the NASA Space Transportation System Payload Data and Analysis (SPDA) data for those automated and sortie payloads planned for flight during the first five years of shuttle operation. The results were reviewed at NASA Headquarters for appropriateness of requirements.

The second step transformed these performance requirements into common technology advancements, which were reviewed with technology specialists at NASA Centers.

During the third step, major revisions were made based on visits to the centers. These revised technology requirements were then mailed back to appropriate personnel at NASA Headquarters and centers and to user/manufacturers for their review and critique.

In step four, appropriate comments obtained from these activities were incorporated into the technology requirement and submitted to NASA/ARC for review and approval.

Because of the nature of the task – the assessment of technology requirements versus the current state of the art – this study necessitated the direct involvement of a large number of NASA and other technical personnel. The study team was under the guidance and review of the NASA/OAST Payload Technology Panel and was monitored and directed by NASA Ames Research Center. The team obtained payload performance

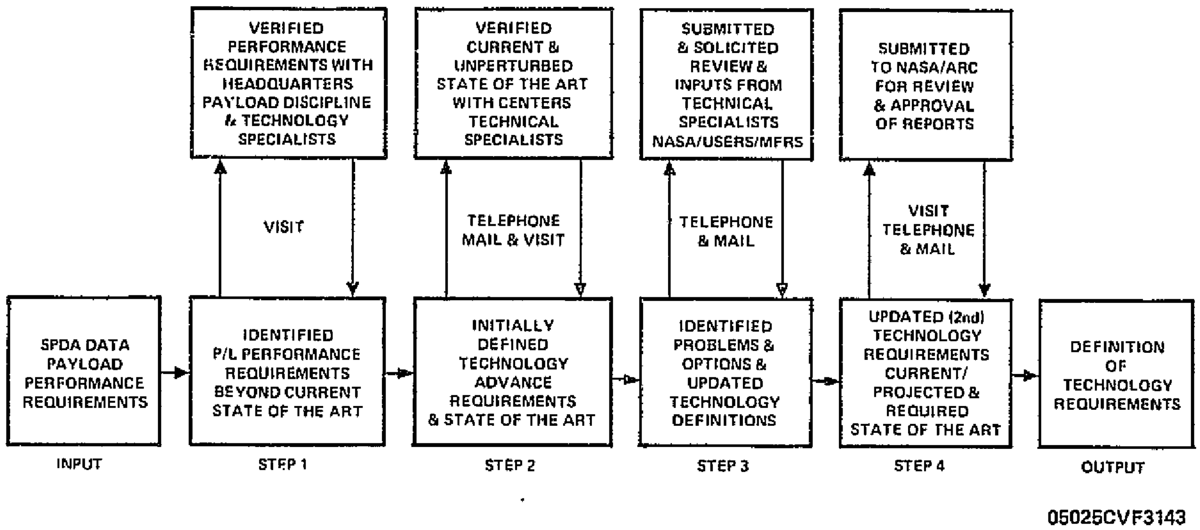

Figure 1. Study Approach

requirements from 15 payload working group discipline spec alists located at NASA Headquarters (Figure 2). The technology state-of-the-art review, across all 19 of the technology categories, was supported by a good cross section of 156 specialists as indicated for the NASA Headquarters, NASA Centers, and the Jet Propulsion Laboratory.

The remaining 51 contributors consisted of university, observatory, research organization, and manufacturer technical personnel. The written response received from 51 of these latter groups represents a 54 percent return on the solicitations. Even though there was no similar data available on this type of review, the response has been very gratifying to the study team. The split between research organizations and manufacturers was somewhat arbitrary, but it was made primarily on the basis as to whether the establishments' major effort was known or judged to be research or manufacturing. Of course, it is recognized that all manufacturers capable of participating in this type of effort are conducting research in the area reviewed.

All personnel represented as contributors in Figure 2 are identified in Appendixes A and B by name, address, and item or subject to which they made a notable contribution.

The results represent a consensus on these technology requirements because of the large participation and review by NASA Headquarters scientific working groups and technology specialists, NASA Centers, JPL, universities, research organizations, manufacturers, and the NASA/OAST Payload Technology Panel.

ARC — OAST PAYLOAD TECHNOLOGY PANEL

STUDY TEAM GD, RI, GE

PAYLOAD PERFORMANCE REQUIREMENTS REVIEWED FOR 12 DISCIPLINES				
NASA HEADQUARTERS PAYLOAD WORKING GROUP DISCIPLINES	ASTRONOMY	EARTH OBS	SPACE TECHNOLOGY	
	HE ASTROPHYSICS	E&O PHYSICS	PLANETARY	
	SOLAR PHYSICS	SP PROCESSING APPL	COMM/NAV	
	ATOM & SP PHYSICS	LIFE SCIENCES	LUNAR	
CONTRIBUTORS: 15				

TECHNOLOGY STATE-OF-THE-ART REVIEW

TECHNOLOGY CATEGORY	HQ	GSFC	LARC	MSFC	JSC	JPL	ARC	LERC	WFC	UNIV/ OBSERV	RESEARCH ORG	MFR	
1. COLLECTORS	X	X	X	X		X	X			X		X	1
2. SENSORS	X	X	X	X	X	X	X	X		X	X	X	2
3. GENERATORS	X	X	X		X		X					X	3
4. SYSTEMS	X	X			X	X	X		X			X	4
5. SPECIAL DEVICES	X	X		X		X	X	X		X		X	5
6. INERTIAL/ELECTROMECHANICAL	X	X										X	6
7. LIFE SCIENCES	X			X	X		X						7
8. CONTAMINATION	X	X		X			X					X	8
9. STRUCTURAL & S/C MECHANICAL	X	X	X	X		X	X			X		X	9
10. ENVIRONMENTAL CONTROL	X	X	X	X	X	X	X				X	X	10
11. ENVIRONMENTAL PROTECTION	X		X			X	X				X		11
12. CRYOGENIC CONTROL	X	X		X	X		X			X	X	X	12
13. GN&C	X		X				X	X			X	X	13
14. PROPULSION	X	X	X				X	X			X	X	14
15. ATTITUDE CONTROL/MEASUREMENT	X	X	X	X		X	X				X	X	15
16. TT&C/DATA	X	X				X	X				X	X	16
17. ELECTRICAL POWER	X	X				X	X	X					17
18. INSTRUMENT ELECTRONICS	X	X			X		X			X	X		18
19. SOFTWARE	X	X				X	X			X		X	19
NUMBER OF CONTRIBUTORS:	12	37	21	17	12	18	24	14	1	6	12	33	
	TOTAL: 156									TOTAL: 51			
NO. SOLICITED BY MAIL:										9	19	67	
										TOTAL: 94			

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Figure 2. Study Participants

1.2.2 TERMINOLOGY USED IN RESULTS. To provide uniformity of terminology and consistency of results within the study and to obtain definitions of what constitutes a satisfactory technology advance, the level of maturity of the state of the art was indicated by ten levels. The levels were derived as a tool for this study and are somewhat arbitrary, but they are judged to have broad application. It appeared that a set with finer structured steps would not improve its utility for this study. The levels are listed in Table 1. Ascending numerical values or levels were assigned to provide a common reference and to facilitate identification and use of the levels. In the application of this scale it should be recognized that the difficulty in going from one step to another will depend on the specific item as well as which step is being made; however, the scale is useful in highlighting the overall technology gaps. These levels of the state of the art were used to assess three areas that are keys to the defined technology requirement. These are:

a. Current State of the Art: To what level has the technology which more nearly fits the requirement been carried to date.

b. Unperturbed Advancement: To what level is the technology expected to be by need date if NASA expends no special effort in this area beyond current plans. (Some technologies are expected to be advanced by industry or other agencies.)

c. Required Advancement: To what level must the technology be carried to make it acceptable for its intended use or ready for commitment to a program.

Table 1. Level of State-of-Art Definition

LEVEL	LEVEL DEFINITION	GENERAL AREA
1	BASIC PHENOMENA OBSERVED & REPORTED	THEORETICAL & LABORATORY
2	THEORY FORMULATED TO DESCRIBE PHENOMENA	
3	THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL	
4	PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED; e.g., MATERIAL & COMPONENT	
5	COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN LABORATORY	
6	MODEL TESTED IN AIRCRAFT ENVIRONMENT	PROTOTYPE & OPERATIONAL MODELS
7	MODEL TESTED IN SPACE ENVIRONMENT	
8	NEW CAPABILITY DERIVED FROM AN OPERATIONAL MODEL (A LESSER MODEL OPERATING IN SPACE)	
9	RELIABILITY UPGRADING OF AN OPERATIONAL MODEL	
10	LIFETIME EXTENSION OF AN OPERATIONAL MODEL	

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1.2.3 STUDY RESULTS SUMMARY. A summary of the findings of this study in terms of the levels of technology just described is presented graphically in Figure 3. The state-of-the-art level versus cumulative percent of technology items is shown in Figure 3a. The lower curve gives the current level of the state of the art, while the middle curve indicates the additional expected normal advance by currently planned effort. The larger advance, which must be provided by NASA, is indicated by the separation between the center curve and the upper curve, or levels to which the technology is required to be advanced if the payloads are to perform their expected missions. Since each curve is independently cumulated, the level of advance for an individual item is not identifiable in this graph; but the area between the respective curves is indicative of the relative magnitude of the required effort. The upper curve shows that only about 22 percent of the technology items can be satisfied in the laboratory, level 5, and be ready for application or commitment to a program, whereas the remainder require some type of demonstration in an aircraft environment (level 6 or higher).

The second set of curves (Figure 3b) presents the number of steps of advancement between current and required versus cumulative percent, as well as that between unperturbed and required advancement. There is a small but significant difference between the two. Here the differences were taken before calculation of percentage. The upper two curves show the overall magnitude of the advance required. For the current to required, 34 percent of the items require only one step, whereas the upper 3 percent require five steps, and the average number of steps for all the items is 2.2. For the unperturbed to required, the average number of steps is 1.75.

The lower curve provides insight into how fast the technology must be advanced. It was derived by ratioing the number of steps to the number of years beginning in 1975 and counting up to the year in which the technology will be needed to support the payload development for flight in the early 1980s. A rate of one or more levels per year is considered critical and occurs for about 20 percent of the items.

The degree of difficulty in advancing the state of the art will depend not only on the number of levels to be advanced but where in the chain of advancement one is operating; and probably more importantly, it will depend on the specific item itself. In any event, since the unperturbed advance falls short of the required advance in 84 out of the 91 items, NASA should provide the major effort for the technology required of the payloads, otherwise the project schedule may be unduly delayed, cost increased, or the planned research may fail.

1.3 STUDY TEAM

The study was performed under the guidance and review of the NASA/OAST Payload Technology Panel and administered by Ames Research Center as indicated in Figure 4. The study was conducted by a contractor team led by Convair Division of General Dynamics and supported by Rockwell International Space Division and General Electric Space Division, with each team member having specific areas of responsibility related to their technology expertise.

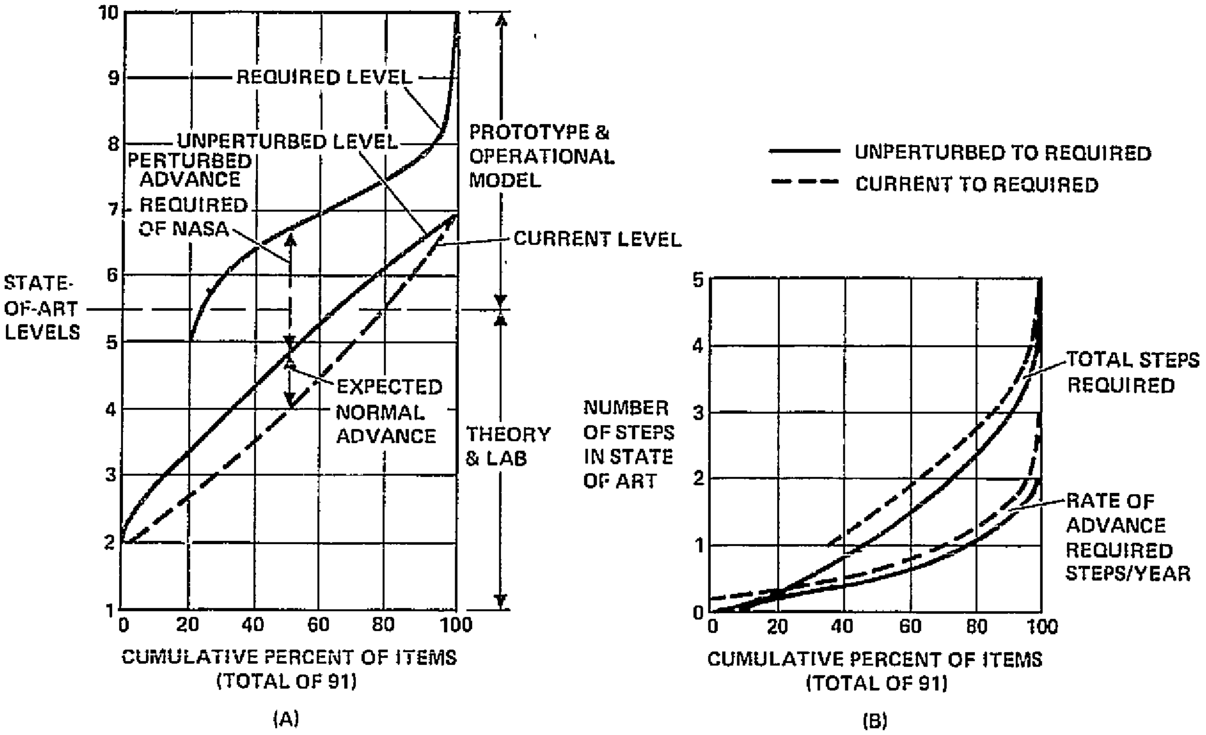

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Figure 3. Summary Results

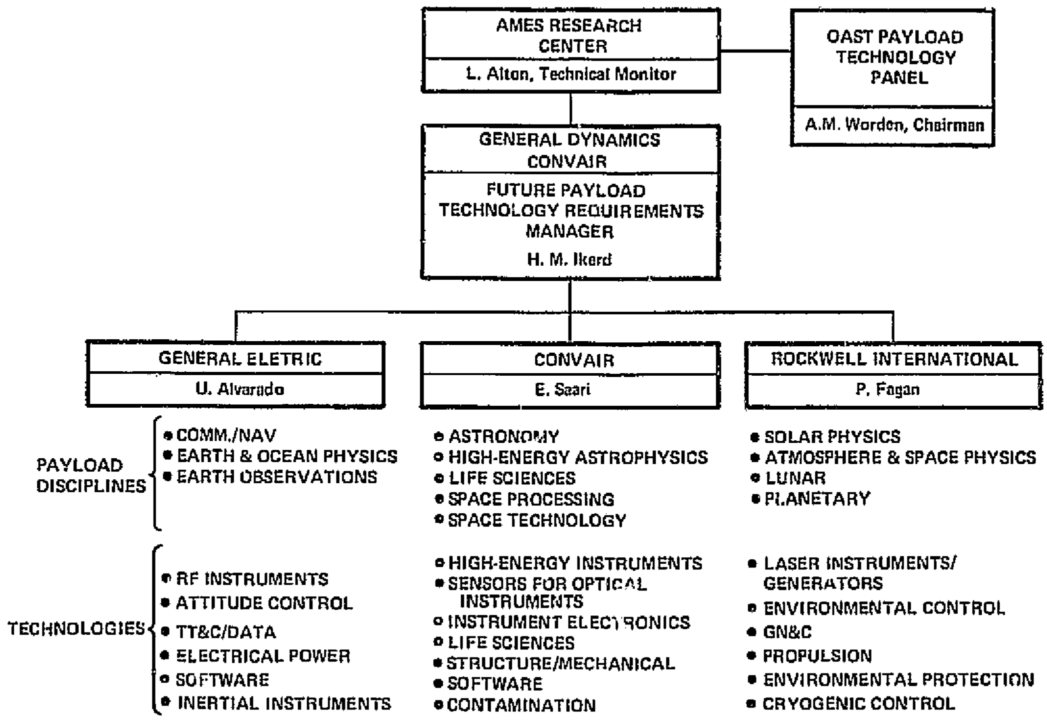

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Figure 4. Study Responsibility

The responsibility for determining payload performance or characteristic parameters estimated to be beyond the current state of the art was assigned among the 12 payload disciplines used in the NASA SPDA activity. This allowed maximum use to be made of the team members' knowledge of the payload requirements gained from prior participation in the SPDA activity.

The responsibility for defining the advancement of the technology required to provide the payload performance was also assigned to technology specialists so that a solution or concept found for a requirement in one discipline could then be applied in others as appropriate. This approach allowed ready identification of commonality of requirements, thus minimizing the number of technology items to be defined.

SECTION 2

OBJECTIVES AND RELATIONSHIP TO NASA PROGRAMS

The objectives of the Future Payload Technology Requirements Study were to: 1) analyze the NASA payloads listed in the NASA 1973 Payload Model - with emphasis on those for the first five years of STS operation - to determine their performance or characteristic parameters estimated to be beyond the current state of the art, 2) define the technology advances required for these payloads to accomplish their objectives, and 3) identify the characteristics of these technology advances that will effectively assist the NASA technology effort.

A required technology advancement for purposes of this study is defined as any technology effort required to bring a concept through the feasibility and practicability determination phase (i. e., experimental laboratory or space environment demonstration) to the point at which the concept could confidently be included in the design of a new project and successfully pass full-scale prototype tests with low risk.

NASA is developing the Space Transportation System and the Spacelab, which will support the scientific and applications payloads analyzed in this study. Any payload performance that must be extended beyond that which is currently available needs to be accomplished within the appropriate time frame afforded by the STS/Spacelab schedules. An additional and important aspect is that the results of this study will be useful to NASA in its search for technology commonality in the Space Transportation System, Space Lab, and Payload Programs.

SECTION 3

METHOD OF APPROACH

The approach used in this study was aimed at producing the most credible results possible. The nature of the task — assessment of technology requirements versus current state of the art — necessitated involving directly a large number of NASA and user/manufacturer technical personnel.

The Future Payload Technology Requirements analysis was performed in four main steps, time phased over a span of approximately eight months (Figure 5). These steps are:

a. Payload requirements analysis.

b. Preliminary technology requirements definition.

c. Verification of technology requirements/status.

d. Data update and documentation.

First, the payload advancement requirements were developed primarily by reviewing the July 1974 Level B SPDA data for Automated and Sortie payloads, which are those to be supported by the Space Transportation System during its first five years of operation. The data was screened for areas of payload performance requirements that were indicated to be beyond the current state of the art. The data was consolidated and

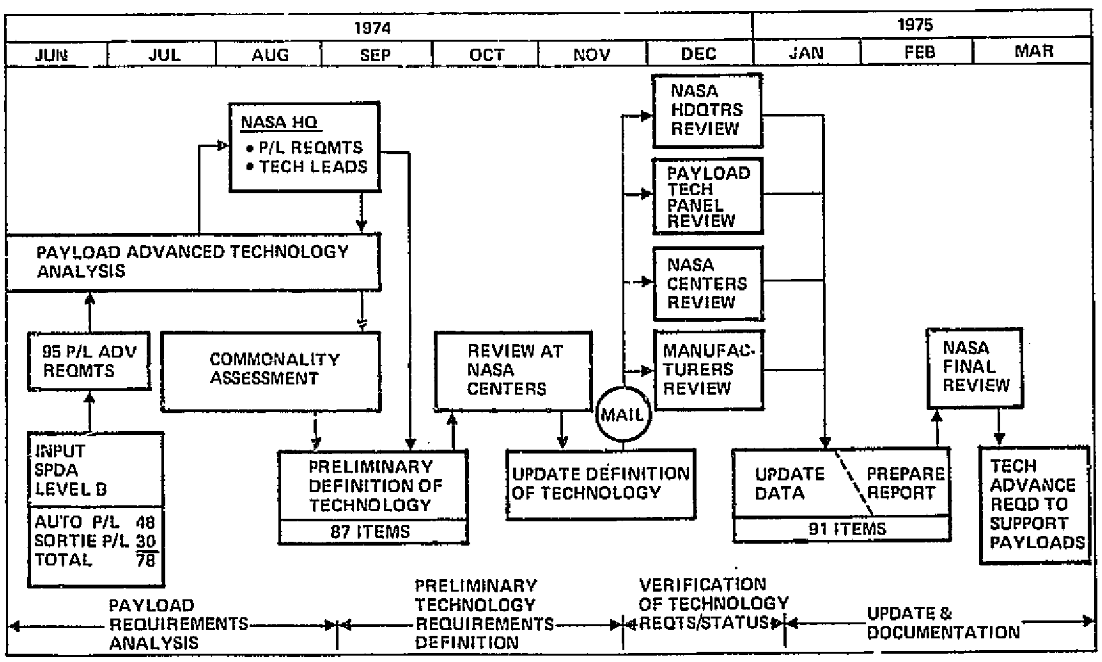

Figure 5. Payload Advanced Technology Analysis Flow/Schedule

augmented by the contractor Payload Specialists. The Payload Technology Panel was briefed on the findings at the first progress review in mid August 1974.

These interim findings were presented and discussed with individual discipline specialists and subsystem and technology specialists at NASA Headquarters during the same visit. The discussions concerned:

a. Early study results — feedback and comments on these findings.

b. Other technology requirements — additional items of concern or need as seen by the specialists.

c. Contacts at NASA Centers — other specialists who are knowledgeable in the area and could be of assistance in confirming state of the art.

An assessment of the commonality of these payload performance requirements was made, and preliminary technology advances (87 items) required to support these payload requirements were identified.

During the early part of the second step a first version of the technology definitions, based on the payload requirements, was made to obtain an understanding of the technology advances required and how they would relate to the state of the art. These technology findings were forwarded to previously identified knowledgeable specialists at the NASA Centers and JPL a few days before the visit. Visits were planned and scheduled as to date and hour, then confirmed or revised by telephone. Each item was reviewed on a one-for-one basis with the specialists during the visits. The discussions usually lasted from one to three hours and involved from two to six persons. Major topics discussed were: current state of the art versus requirements, expected advances, foreseen problems, and current or planned research work going on in the field. This collected data and information were used as the basis for revising the technology items and determining sources of information outside NASA.

The third and major step was that of updating the technology requirement definition, including the identification of options, potential problems, and technology schedule estimates. These revised technology definitions were mailed to NASA technology and discipline specialists for their review to verify that their applicable inputs had been properly interpreted and incorporated. A similar mailing was conducted with universities, manufacturers, and research organizations to obtain their review and critique of state-of-the-art assessment, options, potential problems, and technology schedule.

In the case of NASA, selected items, as well as supporting or related items, were sent to those who had previously contributed to them. For the other groups; e.g., manufacturers/users, interest was established or confirmed by telephone in most cases.

The fourth step consisted of incorporating all appropriate revisions suggested by the results of the previous step and preparing the summary and final reports.

In summary, the inputs have included verbal and written comments and data from NASA Headquarters, NASA Centers, Jet Propulsion Laboratory, and one university, University of California at Berkeley, to which a visit was made. Written comments and supporting data and references were received from the other contributors. The participants' major contributions have been as follows:

NASA Headquarters: Review and verification of payload performance requirements and identification of cognizant technology specialists at the centers.

NASA Centers: Review and verification of the state of the art of technology items and identification of planned programs.

Universities, Research Organizations, and Manufacturers: Review of the current state of the art, technology problems/options, unperturbed technology advancement, and technology advancement schedule.

All participants in this study are identified in Appendixes A and B. Their distribution by technology category was given in Figure 2, and their geographic distribution is indicated in Figure 6.

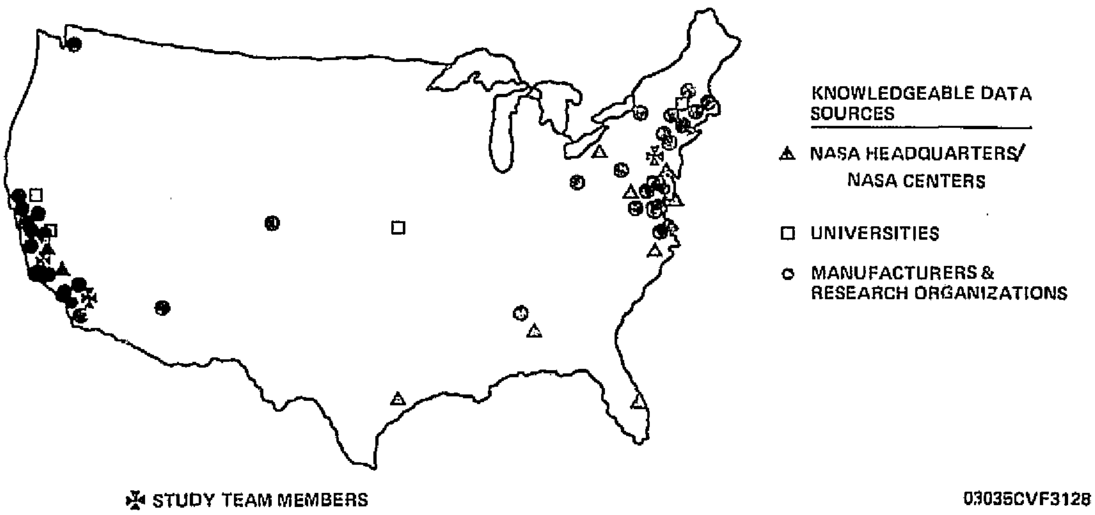

Figure 6. Geographic Distribution of Participants

SECTION 4
RESULTS

The overall results of this study show that a large number of technology items require advancement and that NASA will be required to provide most of this advancement. These items are identified and their state-of-the-art levels along with need dates documented. The type of detail data provided by this study is described below.

4.1 STATE-OF-THE-ART LEVEL

The levels of the state of the art for the technology items are summarized graphically in Figure 7 for overall visibility. The ordinate indicates the various technology levels. The items represented by individual vertical lines are in numerical sequence within a technology category. The lower end of the line indicates the current level of the state of the art, while the upper end indicates the level to which it has been estimated that the technology should be advanced to meet the intended application (see legend in Figure 7).

The circle on the line indicates the unperturbed level or expected normal advancement by the time the item is needed. Since NASA must provide the main advancement beyond the unperturbed level, this level becomes the significant reference point. Some steps may be bypassed or not required in a specific item. Detail planning of the technology development would indicate what should be done.

The length of the line is indicative of the magnitude of the task required to advance that particular item from the current or the unperturbed level, as the case may be. For example, the sensor item 2.10, which is a VIS-IR luminescence mapper, (see insert in Figure 7) requires level 6; i.e., a demonstration in an aircraft environment. It is indicated to be at the current level of 3 but is expected to be advanced to level 5 or be demonstrated in the laboratory by the technology need date, estimated to be 1976. One additional step, from level 5 to level 6, is necessary to bring the item to required maturity level, which is flight test in an aircraft before commitment.

For a second example, even if the line is short, which is the case of item 1.1 (the large gamma ray survey instrument), a problem of advancement may be significant. The sensitivity and spatial resolution is to be advanced in this requirement. An increase in area by a factor of 130 is indicated for this instrument, and at the same time it must maintain high efficiency and energy resolution. A similar but much smaller instrument has been operated in space. The extrapolation of its performance to the level of this new requirement is judged to be a major technology problem.

When the need date is imposed on the number of steps and a rate of advancement number of steps per year is determined, the problem in the first case, sensor item 2.10, is seen to be very critical if the unperturbed level should remain at the current level. A rate of

LEVEL OF STATE OF ART DEFINITIONS

1. BASIC PHENOMENA OBSERVED AND REPORTED
2. THEORY FORMULATED TO DESCRIBE PHENOMENA
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT
7. MODEL TESTED IN SPACE ENVIRONMENT
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL

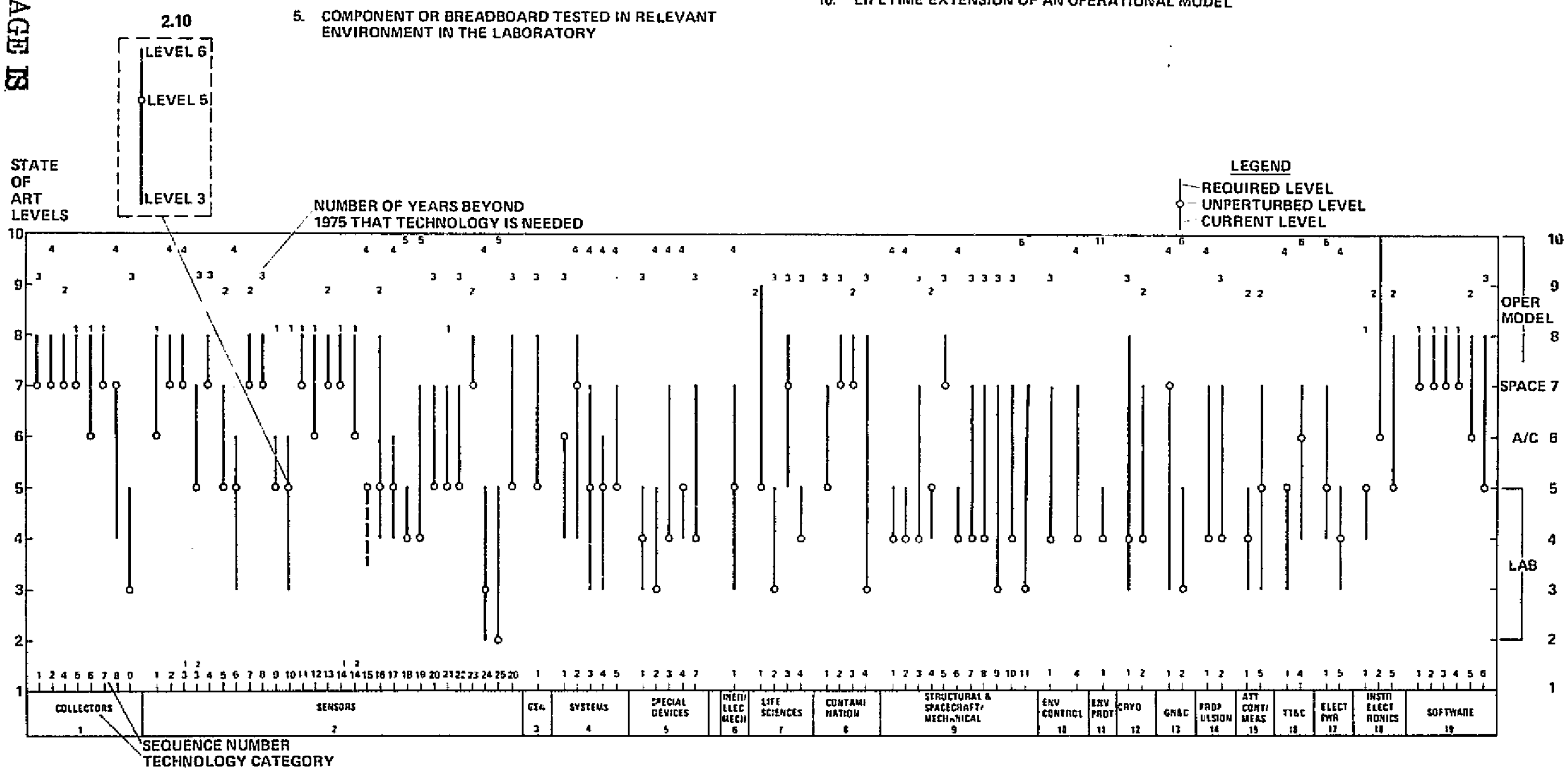

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Figure 7. State of Art Levels

3 steps per year is required, counting from 1975. However, the rate does become more reasonable, or one step per year, if the unperturbed level is used as the reference. The number of years from 1975 to the need date of the technology is indicated by the numbers 1 to 11 along the upper part of the chart.

The number of steps in change of level of the state of the art shown for each item in Figure 7 is used to summarize the number of items by level, as given in Figure 8. The chart on the left shows that more than one-half of the items require an advancement of more than one magnitude level. The magnitude of the problem is indicated, but the criticality – discussed in the next section – is dependent also on the time factor.

The second chart in Figure 8 shows how the payload population, to which the technologies will benefit, fits into the picture. Its shape is substantially the same as that of the other chart, which tends to show that the number of technology items in the respective steps is proportional to the number of payloads that benefit from them. In other words, the technology advancement required is fairly well distributed throughout the payloads reviewed for applicability.

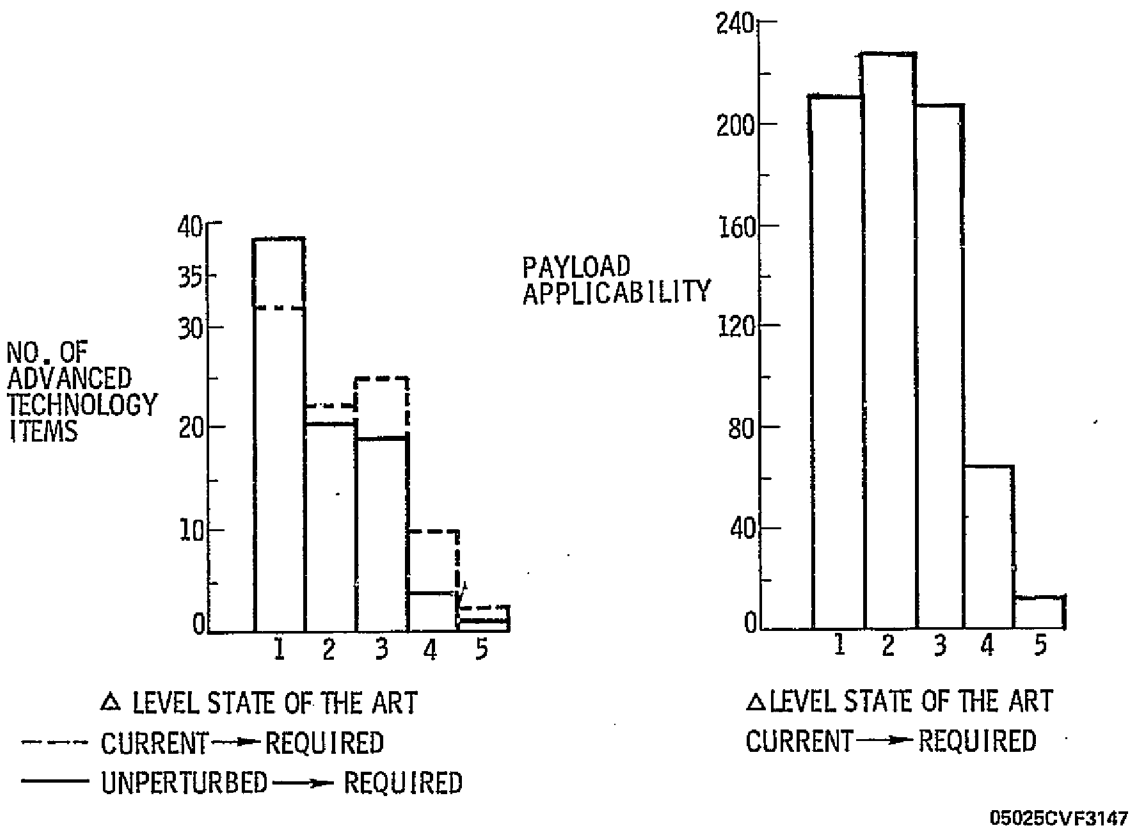


Figure 8. Technology Items Summarized by Steps in State-of-Art Level

4.2 TIME FACTOR IN TECHNOLOGY ADVANCEMENT

The previous section discussed magnitude of technology advancement; however, the time to make the advancement can be critical when the rate exceeds approximately one step per year.

The three-dimensional histogram in Figure 9a shows the number of technology items for the various delta levels of the state of the art and the year in which the technology is needed. Most of the items are required to be satisfied within the first four years and are fairly well distributed. For example, approximately one-fourth of the items become due each year. There is a flat peak of 29 items in the third year. Items that fall near the lower right corner of the chart have the potential of requiring the most and immediate attention.

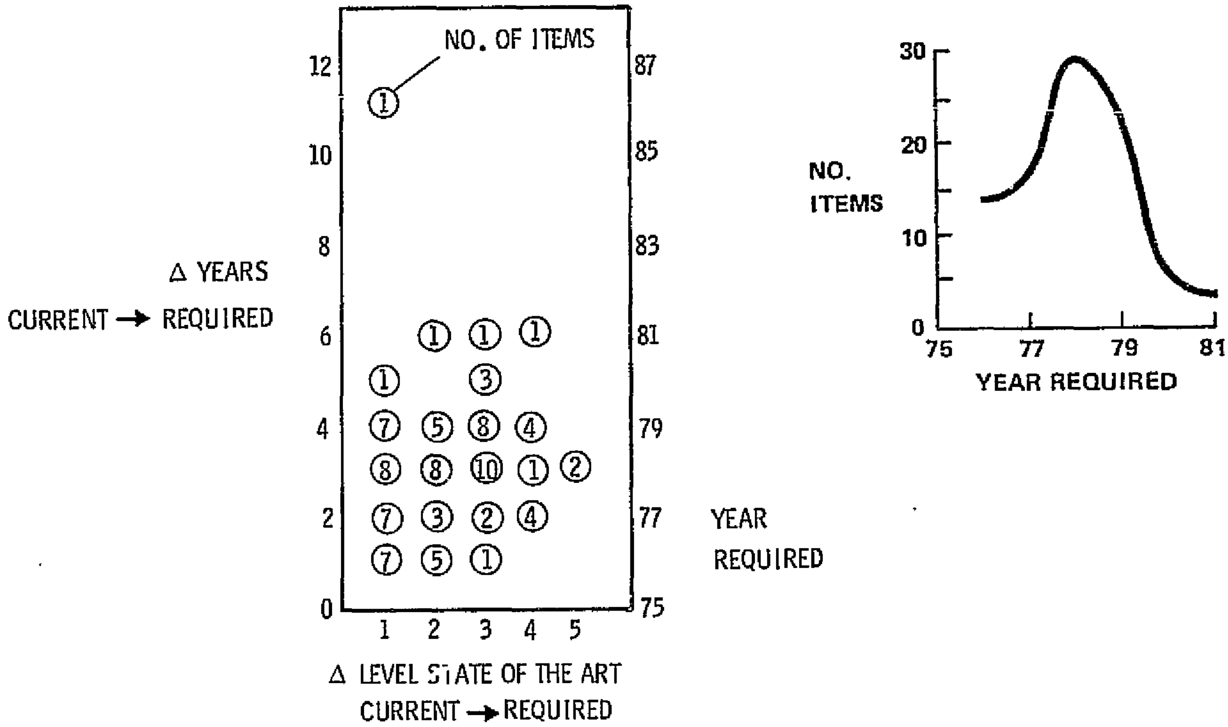
The chart in Figure 9b shows how the items vary with rate of advancement. Technology items considered critical are identified by numbers and descriptive titles. For example item 2.21, which is large electrographic camera, is beneficial to astronomy payloads. The required resolution and field size is a factor of two better than current technology in the laboratory, which is level 5. The technology advancement could be satisfactorily demonstrated on a rocket flight, a level 7, which is testing in the space environment. The need date for this demonstration is 1976; therefore the required rate is two steps per year. The currently planned effort is not expected to move the technology beyond the current level of 5; therefore NASA must provide a substantial effort at a fairly high rate.

A second example is item 8.4, which has to do with development of techniques and/or equipment contamination avoidance. This technology is required in 1978; it has been carried only to level 3 and needs to be demonstrated on the initial shuttle test flights, then finally tested on selected optical model telescope payloads on shuttle sortie missions. The required rate of advancement is 1.6 steps per year. Here again, no one is expected to make appreciable advancement with this item outside NASA. It could be beneficial to all optical type payloads.

4.3 LISTING OF REQUIRED TECHNOLOGY ADVANCEMENTS

Certain payloads in the various scientific and applications disciplines have been identified as benefitting from advancements of the specific technology. The technology items are identified by decimal numbers, which are entered in the applicable discipline column in Table 2. The number preceding the decimal point denotes the technology category, while that following indicates the item sequence in that category. The commonality of application is indicated by the appearance of a particular item number in more than one discipline column.

Of the total 91 items, almost one-third are in the sensor category. This may not be surprising since almost all payloads have some type of sensor (or detector), and the



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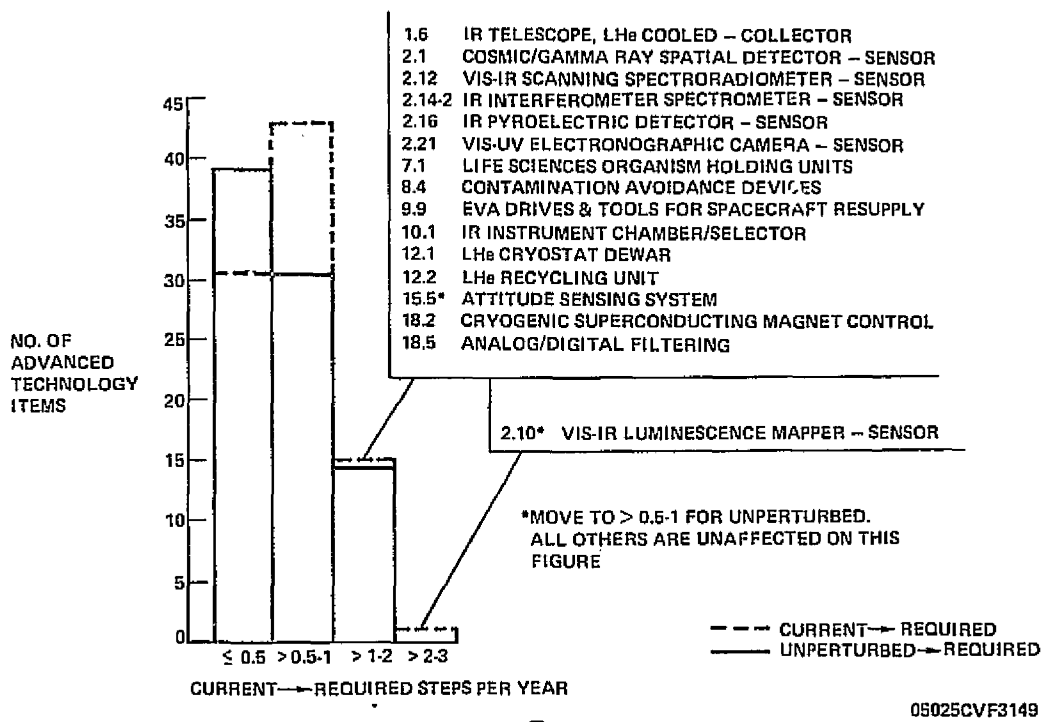

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Figure 9. Technology Need Date and Rate of Advancement Required

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Table 2. Technology Items by Benefiting Discipline

TECHNOLOGY CATEGORY	No. of Items in Category	DISCIPLINE: Astronomy	High Energy Astrophysics	Solar Physics	Atmospheric & Space Physics	Earth Observations	Earth & Ocean Physics	Space Processing Applications	Life Sciences	Space Technology	Planetary	Communication/ Navigation	Lunar
1. Collectors	8	1.4,1.5,1.6	1.1,1.2			1.9	1.7,1.9			1.9		1.8	
2. Sensors	28	2.7,2.14-1, 2.6 2.14-2, 2.19, 2.20,2.21,2.22,	2.1,2.2,2.3-1, 2.3-2,2.4,2.5, 2.6,2.22	2.7,2.22	2.18 2.22 2.26	2.8,2.9,2.10, 2.12,2.13,2.17, 2.22,2.23	2.9,2.13,2.16, 2.22,2.18	2.25	2.18	2.11,2.24, 2.25	2.15, 2.22	2.18	2.22
3. Generators	1											3.1	
4. Systems	5				4.5		4.3,4.4			4.1	4.2		
5. Special Devices	5			5.7		5.7	5.7	5.1, 5.2			5.3	5.4	
6. Inertial/Electromechanical	1						6.1						
7. Life Sciences	4								7.1,7.2 7.3,7.4				
8. Contamination	4	8.1,8.2,8.3,8.4	8.1							8.1,8.2,8.3, 8.4			
9. Structural & Spacecraft Mechanical	11	9.7,9.8,9.9, 9.10,9.11	9.3,9.6,9.7,9.8, 9.9,9.10,9.11	9.4,9.7,9.8, 9.9,9.10,9.11	9.1,9.7 thru 9.11	9.7,9.8,9.9, 9.10,9.11	9.7,9.8,9.9, 9.10,9.11			9.1	9.5	9.2,9.7,9.8, 9.9,9.10,9.11	
10. Environmental Control	2	10.1								10.4			
11. Environmental Protection	1										11.1		
12. Cryogenic Control	2	12.2	12.2		12.1					12.1			
13. GN&C	2										13.1, 13.2		13.2
14. Propulsion	2										14.1	14.2	
15. Attitude Control/Measurement	2	15.1	15.1			15.5							
16. TT&C/Data	2	16.4				16.4					16.1		
17. Electrical Power	2				17.5	17.1	17.1					17.1,17.5	
18. Instrument Electronics	3		18.1,18.2	18.1			18.5						
19. Software (Total number of items - 91)	6	19.1,19.3,19.4, 19.5	19.1,19.3,19.4, 19.5	19.1,19.4,19.5	19.1, 19.5&.6	19.1,19.2,19.3, 19.5,19.6	19.1,19.2, 19.5,19.6	19.1	19.1	19.1	19.1	19.1	19.1

spectrum of measurement is quite varied from sensor to sensor, whereas in the solution of a technology problem in a category such as TT&C, electrical power or instrument electronics can apply to a variety of payloads or even to disciplines.

The technology requirement items are fairly well distributed throughout the disciplines. The specific technology items applicable to each discipline and the payloads within the discipline have been identified.

Table 3 shows the list of the technology items, along with the state-of-the-art levels, need dates, and applicable number of payloads for each item that were used in the analysis and discussions in the preceding sections. Important data included are the differences in levels between the current state of the art and the required state of the art and the technology need dates. As pointed out in the summary, the degree of difficulty in advancing the state of the art will depend not only on the number of levels to be advanced but where in the chain of advancement one is operating, and probably more importantly it will depend on the specific item itself. In any event, since the unperturbed advance falls short of the required advance in 84 out of the 91 items, NASA should provide the major effort for the technology required payloads, otherwise project schedules may be unduly delayed, costs increased, or the planned research may fail.

4.4 DATA PROVIDED ON EACH TECHNOLOGY ITEM

The data provided for each technology item are given in a three-page format. The requirements are stated, state of the art indicated, options and problems identified, and finally a schedule to close the technology gap is shown. The structure of the data form, an example, and a description of content are shown in Figure 10.

Table 3. List of Required Technology Advancement Items

Category Application	Technology† Assignment	Item No.	Technology Item	State of Art			No. of Levels C→R	Need Date	No. of P/L	Remarks
				Current	Unperturbed	Reqd				
COLLECTORS										
Gamma Ray	C	1.1	Large Gamma Ray Survey Instrument – Sensitivity	7	7	8	1	78	2	Area Increased by Factor of x 130
X-Ray	C	1.2	X-Ray Telescope – Sensitivity, Spatial Resolution, FOV	7	7	8	1	79	3	Area Increased by Factor of x 120
UV-IR	C	1.4	Large UV-IR Telescope Optics – Figure, Efficiency	7	7	8	1	77	5	Stray Light Control
IR	C	1.5	Infrared Telescopes – Improved Sensitivity, Minimized Local Flux	7	7	8	1	76	5	Benefits most IR Payloads
IR	C	1.6	LHe Cooled Telescope – Extended Design Lifetime	6	6	8	2	76	1	Minimize Local Flux and Cryogen Usage
IR	C	1.7	IR Scanner/Radiometer – Improved Temperature Measurement Accuracy	7	7	8	1	77	1	IFOV vs. Collector Area
VIS-IR	C	1.8	Laser Optical System – Alignment	4	7	7	3	79	1	Several Additional Laser Experiments Planned
Microwave	GE	1.9	Large Microwave Antenna Arrays – Alignment, Flatness	3	3	6	2	78	6	Dimensional Stability vs. Environment
SENSORS										
Cosmic Ray	C	2.1	Cosmic/Gamma Ray Spatial Detectors – Resolution, Stability	6	6	8	2	76	4	Dimensional Stability
X-Ray	C	2.2	X-Ray Transmission Grating – Dimensional Stability	7	7	8	1	79	6	Survive Launch and Orbital Environments
X-Ray	C	2.3-1	X-Ray Maximum Sensitivity Detector – Sensitivity, Charged Particle Rejection	7	7	8	1	79	4	Closed Cycle Cryogenic Cooling System

† C – Convair, GE – General Electric, RI – Rockwell International

Category Application	Technology† Assignment	Item No.	Technology Item	State of Art			No. of Levels C→R	Need Date	No. of P/L	Remarks
				Current	Unperturbed	Reqd				
SENSORS (Contd)										
X-Ray	C	2.3-2	X-Ray Polarimeter – Sensitivity, Dimensional Stability	5	5	7	2	78	4	Crystal Slab Thermal & Dimensional Control
X-Ray	C	2.4	X-Ray Proportional Counter – Spectral, Spatial & Temporal Resolution	7	7	8	1	78	4	Wire Grid vs. Solid State Arrays
X-Ray	C	2.5	Modulation Collimated Scintillation Counters – Spatial Resolution	5	5	7	2	77	2	Mechanical Modulation
X-Ray	GE	2.6	X-Ray Converter/Intensifier – Increased Resolution, Variable FOV	3	5	7	4	79	1	Desire 10^8 Picture Elements/Frame Resolution
UV	C	2.7	Echelle Spectrograph – Increased Sensitivity & Spectral Resolution	7	7	8	1	77	5	Structural Stability, Stray Light Control
VIS-IR	C	2.8	VIS-IR Mapper/Sensor Assy. – Improved Accuracy, Resol., IFOV	7	7	8	1	78	4	Mechanically Scanned vs. Static Matrices
VIS-IR	C	2.9	Thematic Mapper – Improved Registration Accuracy	5	5	6	1	76	4	Improvement Factor X 10
VIS-IR	C	2.10	VIS-IR Luminescence Mapper – Improved Spectral Resolution	3	5	6	3	76	1	Detection within Fraunhofer Lines Spectral Bands
VIS-IR	C	2.11	VIS-IR Mapper for Coastal Zone Oceanography – Accuracy, Resolution, IFOV	7	7	8	1	76	1	Multispectral Line Scanners
VIS-IR	C	2.12	Scanning Spectroradiometer – Improve Accuracy, Reduce IFOV	6	6	8	2	76	2	Multispectral Radiometric Measurements

† C – Convair, GE – General Electric, RI – Rockwell International

Table 3. List of Required Technology Advancement Items, (Contd)

Category Application	Technology† Assignment	Item No.	Technology Item	State of Art Current	State of Art Unperturbed	State of Art Reqd	No. of Levels C→R	Need Date	No. of P/L	Remarks
SENSORS (Contd)										
VIS-IR	C	2.13	Ocean Scanning Spectrophotometer – Improve Accuracy, Reduce IFOV	7	7	8	1	77	2	Multiband Radiometric Measurements
IR	C	2.14-1	IR Photometer – Select Various Narrow Bands in 2-1000 m Range	7	7	8	1	76	3	Compatible with Cryogenically Cooled Telescopes
IR	C	2.14-2	IR Interferometer Spectrometer – Increased Spectral Range & Resolving Power	6	6	8	2	76	5	Thermal Control in 1.5K–2K Range
IR	RI	2.15	IR Interferometer Spectrometer – Reduced Radiation Effects	*	*	5	–	79	1	Operate in Jupiter Radiation Environment
IR	C	2.16	Pyroelectric Detector – Increased Detectivity Without Cryo Cooling	4	5	8	4	77	4	Attempt Room Temperature Operation
Microwave	GE	2.17	Soil Moisture Sensor – Develop All-Weather Capability	4	5	6	2	79	2	Active and/or Passive Microwave Techniques
Microwave	GE	2.18	Range and Range Rate Sensing – Improved Performance, Reduced Size and Weight	4	4	5	1	80	2	Performance Improvement Factor x 10
VIS-UV	C	2.19	High Resolution Photon Counting Detector – Improved Resolution and Dynamic Range	4	4	7	3	80	4	Better Match of Electronic Imaging Device Capability to Optics
VIS-UV	C	2.20	VIS-UV Polarimeter – Improved Sensitivity and Resolution	5	5	7	2	78	2	Multispectral Band Measurements

*There is some DOD activity

† C – Convair, GE – General Electric, RI – Rockwell International

Category Application	Technology† Assignment	Item No.	Technology Item	State of Art Current	State of Art Unperturbed	State of Art Reqd	No. of Levels C→R	Need Date	No. of P/L	Remarks
SENSORS (Contd)										
VIS-UV	C	2.21	Electronographic Camera – Higher Sensitivity, Improved Resolution	5	5	7	2	76	4	Large Area, Large Angle, Noiseless Gain
IR-XUV	C	2.22	Universal Filters – Adjustable Band Pass and Wavelength	5	5	7	2	78	52	Permits High Accuracy Filter Photometry & Broad Application
IR-VIS	C	2.23	Advanced Atmospheric Sensors Group – Improved Accuracy, Selectivity and Resolution	7	7	8	1	77	3	Measure Atmospheric Pollutants and Natural Constituents
Gravity Measurement	GE	2.24	G-Jitter Determination – Develop Measurement Instrumentation	2	3	5	3	79	12	Define Shuttle and Spacelab Operating Environment
Mass Measurement	GE	2.25	Mass Measurement – Develop Device for Use in Zero G	2	2	5	3	80	2	High Accuracy and Very Small Masses Involved
Relativity	RI	2.26	Precession Gyro – High Accuracy Readout	5	5	[illegible]	3	78	1	Related to Relativity Theory
GENERATORS										
Laser Comm.	RI	3.1	Lasers	5	5	8	3	78	1	Laser Diode Pumping for Nd:YAG Laser Communication
SYSTEMS										
IR	RI	4.1	LIDAR System – Develop Space Qualified System	4	6	6	2	78	1	Cloud Measurements, Aerosol Analysis
IR	RI	4.2	Nephelometer – Analysis of Planetary Atmosphere	4	7	8	4	79	4	Operate in Planetary Environment
Microwave	GE	4.3	Synthetic Aperture Radar – Multifrequency, Wideband	3	5	7	4	79	1	Need Onboard Compensation for Doppler Effect

† C – Convair, GE – General Electric, RI – Rockwell International

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Table 2. List of Required Technology Advancement Items, (Contd)

Category Application	Technology† Assignment	Item No.	Technology Item	State of Art: Current	State of Art: Unperturbed	State of Art: Reqd	No. of Levels C–R	Need Date	No. of P/L	Remarks
SYSTEMS (Contd)										
Microwave	GE	4.4	Wave Height Altimeter – Improve Measurement Precision	3	5	6	3	79	1	Desire All-Weather Capability
Radio	GE	4.5	Transmitter/Coupler System – High Power Xmission – Short Antenna — Re: Wave Length	5	5	7	2	79	1	Automatic Antenna Tuning Devices Required
SPECIAL DEVICES										
Liquid & Solid	GE	5.1	Levitation Unit – Provide Position & Temperature Control	3	4	5	2	78	3	Space Processing in Micro-Gravity
Bio & Organic	GE	5.2	Electrophoretic Column/Fractional Collecting System – Fluid Handling Techniques	3	3	5	2	79	2	Reduced Wall Contamination Necessary
Encke Particles	RI	5.3	Solids Analysis Package – Chemical Analysis of Comet Tail	4	4	7	3	79	2	Measure Small Atomic Mass Units
Radio	GE	5.4	High Power, High Efficiency Transmitter – Communications	4	5	5	1	79	1	Circumvent Plasma Effects
Service	C	5.7	Self Aligning Multipin Electrical Connector Assembly	4	4	7	3	78	9	For resupply & Refurbishment
INERTIAL/ELECTROMECHANICAL										
Gravity	GE	6.1	Accelerometer for Gravity Measurements	3	5	7	4	79	1	Improve Sensitivity Factor x 10^3
LIFE SCIENCES										
Biological	C	7.1	Life Sciences Organism. Holding Units – Development	5	5	9	4	77	2	Environmental Control, Waste Management, Data Interface

† C – Convair, GE – General Electric, RI – Rockwell International

Category Application	Technology† Assignment	Item No.	Technology Item	State of Art: Current	State of Art: Unperturbed	State of Art: Reqd	No. of Levels C–R	Need Date	No. of P/L	Remarks
LIFE SCIENCES (Contd)										
Bio-Functional	C	7.2	Bioresearch Centrifuge – Development	3	3	5	2	78	1	
Electro-Mech	C	7.3	Teleoperator Subsystems – Development	5	7	8	3	78	1	Video Displays, Manipulators, End Effectors
Biological	C	7.4	Surgery in Space-Zero G Techniques	4	4	5	1	78	2	Tool & Instrument Retention, Fluid Confinement
CONTAMINATION										
Optical & Plasma	C	8.1	Active Cleaner – Optical Surfaces	5	5	7	2	80	9	Extend Useful Life Space Optics
IR-X-Ray	C	8.2	Advanced Contamination Monitors – Develop Instrumentation Set for Telescope Internal Monitoring	7	7	8	1	78	9	Sensitivity Improvement Factor x 10
IR-X-Ray	C	8.3	Contamination Process Mechanisms – Better Understanding	7	7	8	1	77	9	Theoretical Models, Lab & Space Experiments
IR-X-Ray	C	8.4	Contamination Avoidance Devices – Development of Techniques & Equip	3	3	8	5	78	9	Improved Protective Measures
STRUCTURAL & SPACECRAFT MECHANICAL										
Plasma & Fields	C	9.1	Instrument Boom, 50m – Alignment and Pointing Accuracy	4	4	5	1	79	5	Dynamic Response, Thermal Effects, Retractability
Free Flyers	C	9.2	Payload Spacecraft Structure – Weight Reduction	4	4	5	1	79	14	Critical for Geosynch Payloads
Cosmic & Gamma Ray	C	9.3	Protective Shell/Cover – Environmental Control	4	4	7	3	78	7	Thermal & Material Protection Without Degrading Signal

† C – Convair, GE – General Electric, RI – Rockwell International

Table 3. List of Required Technology Advancement Items, (Contd)

Category Application	Technology† Assignment	Item No.	Technology Item	State of Art			No. of Levels C→R	Need Date	No. of P/L	Remarks
				Current	Unperturbed	Reqd				
STRUCTURAL & SPACECRAFT MECHANICAL (Contd)										
IR-UV	C	9.4	Metering Structure, Solar Telescopes – Reduce Thermal Sensitivity	4	5	5	1	77	3	Dimensional Stability
Planetary	C	9.5	Entry Probe – Low Weight Heat Shield Technology	7	7	8	1	78	3	Planetary Entry, Large ΔV
X-Ray	C	9.6	Instrument Mount/Selector – X-Ray Detectors	4	4	5	1	79	3	High Dimensional Accuracy vs. Space Environment
Service	C	9.7	Module Resupply Mechanism	4	4	7	3	78	22	In-orbit refurbish/resupply spacecraft
Service	C	9.8	Spacecraft Docking/Deployment & Retention Mechanism	4	4	7	3	78	22	To launch or retrieve S/C while in orbit
Service	C	9.9	EVA Eqpt & Tools for Oper, Repair & Serv of S/C	3	3	7	4	78	22	To resupply and Refurbish S/C in orbit
Service	C	9.10	Remote Manipulator System End Effector Mechanism – Shuttle to Spacecraft	4	4	7	3	78	22	To launch or retrieve or refurbish S/C in orbit
Service	C	9.11	Spacecraft to Tug Docking Mechanisms	3	3	7	4	81	14	Resupply & refurbish Spacecraft in Geosynch orbit
ENVIRONMENTAL CONTROL										
IR	RI	10.1	Chamber/Selector – IR Instruments	4	4	7	3	78	5	Operate at Cryogenic Temperatures at Minimum Losses & Local Flux
CO_2 Desorption	RI	10.4	Zero Gravity Steam Generator – Development	4	4	7	3	79	1	Engineering Model Exists

† C – Convair, GE – General Electric, RI – Rockwell International

Category Application	Technology† Assignment	Item No.	Technology Item	State of Art			No. of Levels C→R	Need Date	No. of P/L	Remarks
				Current	Unperturbed	Reqd				
ENVIRONMENTAL PROTECTION										
Planetary	RI	11.1	Structural/Mechanism – Thermal and Pressure Protection for Payload Instruments	4	4	5	1	86	1	Venusian Surface Environment
CRYOGENIC CONTROL										
Superconduction	RI	12.1	Liquid Helium Cryostat Dewar – Develop Flight Weight Unit	3	4	8	5	78	1	LHe (1.6K) required for Precision Gyro Cooling
IR (Long Mission)	RI	12.2	Liquid Helium Recycling Unit – Develop Low Power, Long Life Unit	4	4	7	3	77	9	Three Systems Under Consideration
GUIDANCE, NAVIGATION & CONTROL										
Planetary	RI	13.1	Long Term Guidance for Low Thrust Technology	3	7	7	4	79	4	Advanced Laser Gyros, Star Trackers, Software
Planetary	RI	13.2	Structures/Mechanism – Automatic & Remote Docking (Return)	3	3	5	2	81	1	Orbital Rendezvous Required Controlling Back Contamination
PROPULSION										
Planetary	RI	14.1	Solar Electric Propulsion Stage – Development of Long Life Thrusters and Power Processor	4	4	7	3	79	4	High Impulse Required for Planetary Mission
Station Keeping	RI	14.2	Ion Engine Propulsion Subsystem – Develop Long Lifetime (10 years) Components	4	4	7	3	78	1	Long Life Station-keeping Thrusters
ATTITUDE CONTROL/MEASUREMENT										
Astronomy & Physics	GE	15.1	Tracker/Field Monitor Assy. – Improved Sensitivity, Accuracy and Stability	3	4	5	2	77	18	Standard Fine Tracker & Correlated Field Monitor
Earth Resources	GE	15.6	Advanced Attitude Sensing System – Increased Accuracy	3	6	7	4	77	9	Accuracy Improvement Factor x 10

† C – Convair, GE – General Electric, RI – Rockwell International

Table 3. List of Required Technology Advancement Items, (Contd)

Category Application	Technology† Assignment	Item No.	Technology Item	State of Art: Current	State of Art: Unperturbed	State of Art: Reqd	No. of Levels C→R	Need Date	No. of P/L	Remarks
TLM, TRACKING & COMMAND										
Planetary	GE	16.1	Data Transmission System for Planetary Entry Probe-to-Bus Data Link	3	5	5	2	79	3	Stringent Size, Weight & Power Constraints
Monitor & Control	GE	16.4	Memory Unit for On-Orbit Functions – Develop Small, High Capacity Unit	4	6	7	3	81	3	Rapid Access & Large Memory
ELECTRICAL POWER										
Planetary & Earth Appl.	GE	17.1	High Voltage Solar Array – Develop Low Weight, High Reliability Components	4	5	7	3	80	14	High Voltage Switching Devices Required
Plasma & Earth Appl.	GE	17.5	High Energy Density Battery – Develop Lightweight, Long Life Battery	3	4	5	2	79	14	Desire Power Density Improvement Factor x 2.5
INSTRUMENT ELECTRONICS										
High Energy	C	18.1	Subnanosecond Pulse Measurement & Correlation Detection	4	5	5	1	76	4	Time Interval Resolution Improvement Factor x 1000
Cosmic Ray	C	18.2	Cryogenic Superconducting Magnet Control – Reduce Charge/Discharge Time	6	6	10	4	77	3	Minimize Lost Time in 7-day Flight
Gravity	C	18.5	Analog/Digital Filtering – Increase to 19-bit Accuracy for Gravity Gradiometer	5	5	8	3	77	1	Minimize Error, Curve Fit

† C – Convair, GE – General Electric, RI – Rockwell International

Category Application	Technology† Assignment	Item No.	Technology Item	State of Art: Current	State of Art: Unperturbed	State of Art: Reqd	No. of Levels C→R	Need Date	No. of P/L	Remarks
SOFTWARE										
All Disciplines	C	19.1	Onboard Software Programs – Develop Low Cost Software for P/L Operations	4	7	8	4	76	80	Cost Reduction Factor
EO&OP Discipline	C	19.2	Software for GN&C – Support High Accuracy Experiment Pointing	7	7	8	1	76	4	Better Accuracy
Astr & High Energy	C	19.3	Software for Attitude Control – Experiment Sensor Pointing	7	7	8	1	78	10	Better Accuracy & Filtering
Astr, HE & Solar Phy	C	19.4	Software for Experiment Control, Monitoring, Data Processing and Data Quality Control	7	7	8	1	78	6	Low Cost Compact Multichannel Exp. Correlation
All Disciplines	GE	19.5	Onboard Processing of Data for Payload Experiment/Operations	6	6	8	2	77	92	User Compatible On-Board Data Processing
All Disciplines	GE	19.6	Data Retrieval and Ground Based Transformation and Distribution	5	5	8	3	78	58	Ground Based Quick Access Data Processing (User Compatibility)

† C – Convair, GE – General Electric, RI – Rockwell International

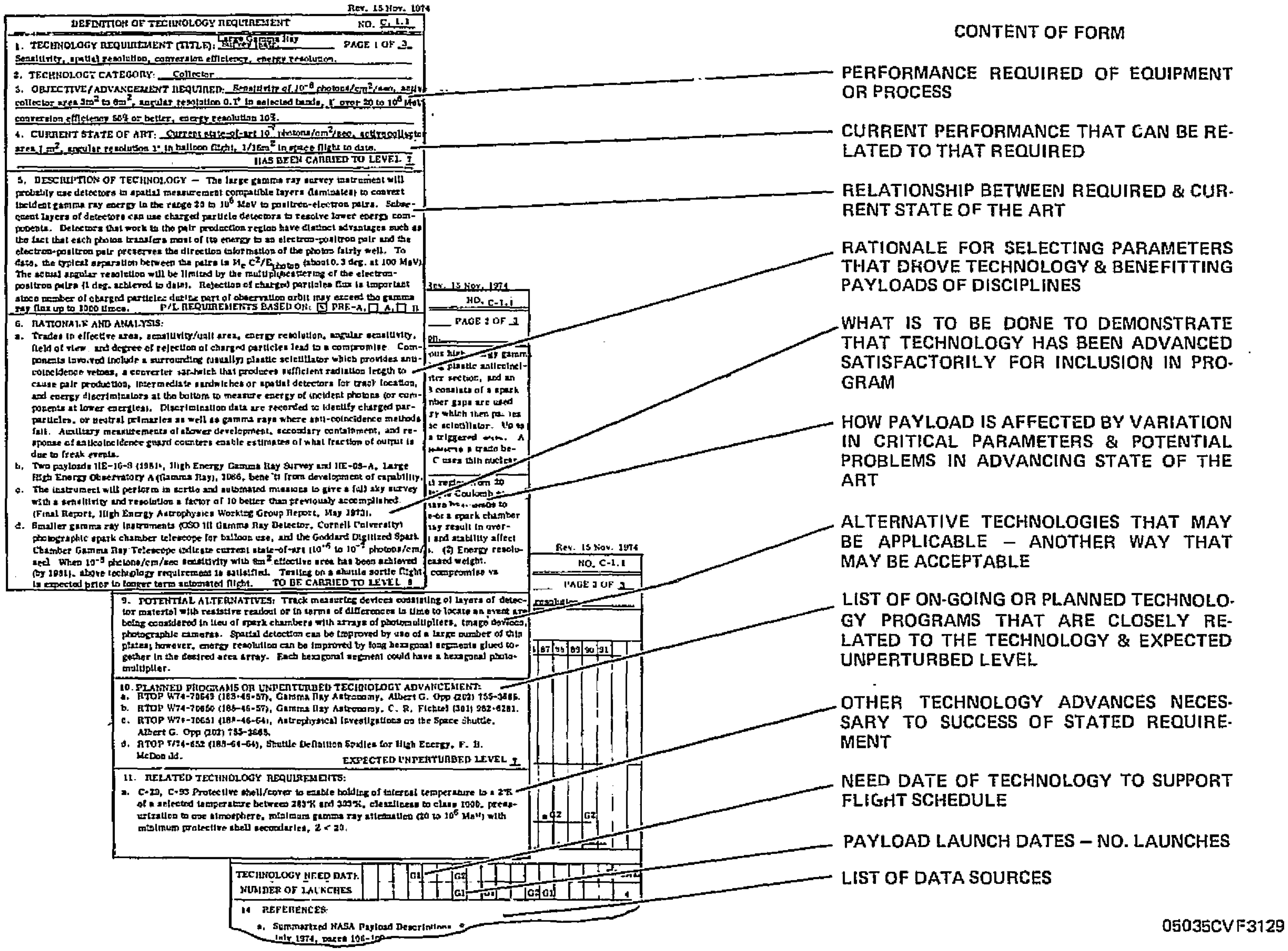

Figure 10. Definition of a Technology

SECTION 5

CONCLUSIONS

Much fundamental understanding of the payload requirements in the scientific and applications disciplines and the technology advancements required to meet these requirements exists respectively within the NASA scientific and technology community. This study has tended to bring into focus and compare, on a one-to-one basis, the requirement versus state of the art.

A large gap exists between the performance requirement and current state of the art for many of the payloads. The scaling laws to make logical extensions are not always understood and require revision as the technology advances. Therefore, the precision of prediction is diminished as the ratio of improvement increases, which is one to two orders of magnitude in the case of some collectors and sensors. There will be an advancement toward closing this gap, but unless NASA provides the resources for it, the advancement will not be sufficient by a large margin. Only 8 percent of the defined technology items will be ready when needed unless NASA provides the major effort for the required technology.

Some technologies require large improvement over that which exist today, some require several levels of advancement, and most are required to be advanced to the required level within the next three to four years to support the NASA payload mission schedule. The time rate of advancement is critical for about one-fifth of the technology items.

The payloads in the second five years of the shuttle era will be more advanced than those planned for the first five years. The study emphasis was on those payloads planned for the first five years whose performance data available for review was defined to level B detail, while the more advanced payloads were defined only to level A. However, the performance requirements of these later payloads are sufficiently well understood to warrant initiation of their review and analysis to ensure that the technology advancements identified here and the subsequent operation of their benefiting payloads do indeed lead to the planning of a technology program that is timely and continuous.

SECTION 6

RECOMMENDED FUTURE EFFORT

Five areas of future work based on the findings of this study are indicated.

a. A direct and logical next step is the development of technology program planning requirements such as the estimate of cost, schedule, and technical benefit of the technology advancement and the selection of the optimum technology advancement approach.

b. NASA is continuing to review and update its payload definitions and performance requirements, therefore the technology advancement requirements should be updated in consonance with that activity. The methodology has been proofed during this study.

c. The definition of software has advanced technology requirements, since software has potential for impact on cost and performace with broad applicability. Software is crucial to basic payload performance.

d. The definition of data processing and distribution technology advancement requirements is important, because the payloads generate an enormous quantity of data. The value of a payload is related to the quantity of information acquired and the timely use of that information. This technology has broad application in that it covers all disciplines and payloads.

e. The assessment of perturbed versus unperturbed technology should be made. Such investigation would determine if any tangible penalties — such as increased payload cost, number of flights, or reduced mission effectiveness — can be identified that are attributed to not achieving the required performance level.

SECTION 7

DEFINITION OF TECHNOLOGY REQUIREMENTS

The payload advanced technology requirements defined in this section were developed primarily by reviewing the July 1974 Level B Space Transportation S stem Payload Data and Analysis (SPDA) data for both Automated and Sortie payloads. The payloads are listed in Tables 4 and 5. The data was screened for areas of technology advancement indicated to be beyond the cur rent state of the art and judged to be required to meet the payload performance requirements. The data was consolidated and augmented by the payload specialists and reported to the NASA Payload Technology Panel at the first progress review in the working paper "Payload Advanced Technology Requirements", Report No. ATR-WP-001, dated 20 August 1974.

The technology advancement required to meet the payload performance requirement has been sorted and assembled by category (e.g., sensors, collectors) as indicated in Table 6. Two preliminary versions of these requirements were contained in working paper reports "Definition of Technology Requirements", Report No. ATR-WP-003, dated 31 October 1974, and "Future Payload Technology Requirements Study", Report No. ATR-WP-004, dated 6 December 1974. The estimates of each technology item identified have been documented on a basic three-page form with additional continuation sheets as required. The current state of the art is indicated for each item, the requirement stated, alternatives and problems identified and, finally, a schedule to close the technology gap is shown. The format and instructions for filling out the form are shown in Figure 11.

Certain payloads in the various scientific and applications disciplines have been identified as benefiting from advancements of the specific technology. The technology items were identified to the applicable disciplines in Table 2, page 4-6.

The technology requirements as defined in this study are presented in the forms that follow. The letter or letters preceding the item number have significance only in that they identify the study team member responsible for that item. Through the process of combining one or more items with another, or dropping some because the investigations show that the requirements were within the state of the art, a few gaps in the numerical sequence will be observed. Table 7 identifies the disposition of the missing items.

The symbols used in the definition forms are given in Table 8. The technology definition forms by category versus page location is given in Table 9 on page 7-11.

Table 4. SPDA Automated Payloads

Note: Number in title is payload code number used in October 1973 NASA Payload Model.

ASTRONOMY

*AS-01-A – LARGE SPACE TELESCOPE (AST-6)
*AS-02-A – EXTRA CORONAL LYMAN ALPHA EXP (AST-1)
*AS-03-A – COSMIC BACKGROUND EXPLORER (AST-1)
AS-05-A – ADVANCED RADIO EXPLORER (AST-1)
AS-07-A – 3.0M AMBIENT TEMPERATURE IR TELESCOPE (NEW)
AS-11-A – 1.5M IR TELESCOPE (NEW)
AS-13-A – UV SURVEY TELESCOPE (NEW)
AS-14-A – 1.0M UV-OPTICAL TELESCOPE (AST-8)
AS-16-A – LARGE RADIO OBSERVATORY ARRAY (AST-8)
AS-17-A – 30M IR INTERFEROMETER (NEW)

HIGH ENERGY ASTROPHYSICS

*HE-01-A – LARGE X-RAY TELESCOPE FACILITY (AST-9)
*HE-03-A – EXTENDED X-RAY SURVEY (AST-5)
HE-05-A – HIGH LATITUDE COSMIC RAY SURVEY (AST-5)
*HE-07-A – SMALL HIGH ENERGY SATELLITE (PAY-1)
*HE-08-A – LARGE HIGH ENERGY OBSERVATORY A (AST-5)
*HE-09-A – LARGE HIGH ENERGY OBSERVATORY B (AST-4)
HE-10-A – LARGE HIGH ENERGY OBSERVATORY C (AST-5)
*HE-11-A – LARGE HIGH ENERGY OBSERVATORY D (AST-9)
HE-12-A – COSMIC RAY LABORATORY (PHY-5)

SOLAR PHYSICS

SO-02-A – LARGE SOLAR OBSERVATORY (AST-2)
*SO-03-A – SOLAR MAXIMUM SATELLITE (AST-3)

*REQUIREMENTS DEFINED TO LEVEL B (48 PAYLOADS)

ATMOSPHERIC & SPACE PHYSICS

*AP-01-A – UPPER ATMOSPHERE EXPLORER (PHY-1)
*AP-02-A – MEDIUM ALTITUDE EXPLORER (PHY-1)
*AP-03-A – HIGH ALTITUDE EXPLORER (PHY-1)
*AP-04-A – GRAVITY & RELATIVITY SATELLITE – LEO (PHY-2)
*AP-05-A – ENVIRONMENTAL PERTURBATION SATELLITE-MISSION A (PHY-3)
AP-06-A – GRAVITY & RELATIVITY SATELLITE-SOLAR (PHY-2)
AP-07-A – ENVIRONMENTAL PERTURBATION SATELLITE-MISSION B (PHY-3)
AP-08-A – HELIOCENTRIC & INTERSTELLAR SPACECRAFT (PHY-4)

EARTH OBSERVATIONS

EO-07-A – ADVANCED SYNCHRONOUS METEOROLOGICAL SATELLITE (EO-7)
*EO-08-A – EARTH OBSERVATORY SATELLITE (EO-3)
*EO-09-A – SYNCHRONOUS EARTH OBSERVATORY SATELLITE (EO-4)
*EO-10-A – APPLICATIONS EXPLORER (SPECIAL-PURPOSE SATELLITE (EO-5)
*EO-12-A – TIROS 'O' (EO-6)
*EO-56-A – ENVIRONMENTAL MONITORING SATELLITE (NN/D-8)
*EO-57-A – FOREIGN SYNCHRONOUS METEOROLOGICAL SATELLITE (NN/D-9)
*EO-58-A – GEOSYNCHRONOUS OPERATIONAL METEOROLOGICAL SATELLITE (NN/D-10)
EO-59-A – GEOSYNCHRONOUS EARTH RESOURCES SATELLITE (NN/D-12)
*EO-61-A – EARTH RESOURCE SURVEY OPERATIONAL SATELLITE (NN/D-11)
EO-62-A – FOREIGN SYNCHRONOUS EARTH OBSERVATORY SATELLITE (NN/D-13)

Table 4. SPDA Automated Payloads (Cont'd)

EARTH & OCEAN PHYSICS

*OP-01-A	–	GEOPAUSE (EOP-4)
*OP-02-A	–	GRAVITY GRADIOMETER (EOP-5)
*OP-03-A	–	MINI-LAGEOS (EOP-6)
*OP-04-A	–	GRAVSAT (EOP-7)
*OP-05-A	–	VECTOR MAGNETOMETER SATELLITE (EOP-8)
*OP-06-A	–	MAGNETIC FIELD MONITOR SATELLITE (EOP-9)
*OP-07-A	–	SEASAT -B (EOP-3)
OP-51-A	–	GLOBAL EARTH & OCEAN MONITOR SYSTEM (NN/D-14)

SPACE PROCESSING

*SP-01-A	–	SPACE PROCESSING FREE FLYER (NEW)

LIFE SCIENCES

*LS-02-A	–	BIOMEDICAL EXPERIMENT SCIENTIFIC SATELLITE (LS-1)

SPACE TECHNOLOGY

*ST-01-A	–	LONG DURATION EXPLOSURE FACILITY (ST-1)

COMMUNICATIONS/NAVIGATION

*CN-51-A	–	INTELSAT (NN/D-1)
*CN-52-A	–	U.S. DOMSAT 'A' (NN/D-2)
*CN-53-A	–	U.S. DOMSAT 'B' (NN/D-2)
*CN-54-A	–	DISASTER WARNING SATELLITE (NN/D-3)
*CN-55-A	–	TRAFFIC MANAGEMENT SATELLITE (NN/D-4)
*CN-56-A	–	FOREIGN COMMUNICATIONS SATELLITE (NN/D-5)
*CN-58-A	–	U.S. DOMSAT 'C' (NN/D-2)
CN-59-A	–	COMMUNICATIONS R&D/PROTOTYPE SATELLITE (NN/D-6)
CN-60-A	–	FOREIGN COMMUNICATIONS SATELLITE B (NN/D-5)

*REQUIREMENTS DEFINED TO LEVEL B (48 PAYLOADS)

PLANETARY

*PL-01-A	–	MARS SURFACE SAMPLE RETURN (PL-7)
PL-02-A	–	MARS SATELLITE SAMPLE RETURN (PL-8)
*PL-03-A	–	PIONEER VENUS MULTIPROBE (PL-10)
PL-07-A	–	VENUS RADAR MAPPER (PL-11)
PL-08-A	–	VENUS BUOYANCY PROBE (PL-12)
PL-09-A	–	MERCURY ORBITER (PL-13)
PL-10-A	–	VENUS LARGE LANDER (PL-14)
*PL-11-A	–	PIONEER SATURN/URANUS FLYBY (PL-18)
*PL-12-A	–	MARINER JUPITER ORBITER (PL-19)
*PL-13-A	–	PIONEER JUPITER PROBE (PL-20)
PL-14-A	–	SATURN ORBITER (PL-21)
PL-15-A	–	URANUS PROBE/NEPTUNE FLYBY (PL-22)
PL-16-A	–	GANYMEDE ORBITER/LANDER (PL-23)
*PL-18-A	–	ENCKE RENDEZVOUS (PL-26)
PL-19-A	–	HALLEY COMET FLYBY (PL-27)
PL-20-A	–	ASTEROID RENDEZVOUS (PL-28)
*PL-22-A	–	PIONEER SATURN PROBE (PL-17)

LUNAR

*LU-01-A	–	LUNAR ORBITER (LUN-2)
LU-02-A	–	LUNAR ROVER (LUN-3)
LU-03-A	–	LUNAR HALO SATELLITE (LUN-4)
LU-04-A	–	LUNAR SAMPLE RETURN (LUN-5)

31 SHUTTLE DELIVERED P/L
50 SHUTTLE + TUG DELIVERED P/L

Table 5. SPDA Sortie Payloads

ASTRONOMY

*AS-01-S — 1.5M CRYOGENICALLY-COOLED IR TELESCOPE
*AS-03-S — DEEP SKY UV SURVEY TELESCOPE
*AS-04-S — 1M DIFFRACTION LIMITED UV OPTICAL TELESCOPE
*AS-05-S — VERY WIDE FIELD GALACTIC CAMERA
AS-06-S — CALIBRATION OF ASTRONOMICAL FLUXES
AS-07-S — COMETARY STIMULATION
AS-08-S — MULTIPURPOSE 0.5M TELESCOPE
AS-09-S — 30M IR INTERFEROMETER
AS-10-S — ADV. XUV TELESCOPE
AS-11-S — POLARIMETRIC EXPERIMENTS
AS-12-S — METEOROID SIMULATION
AS-13-S — SOLAR VARIATION PHOTOMETER
AS-14-S — 1.0M UNCOOLED IR TELESCOPE
*AS-15-S — 3.0M AMBIENT TEMP. IR TELESCOPE
AS-18-S — 1.5 KM IR INTERFEROMETER
AS-19-S — SELECTED AREA DEEP SKY SURVEY TELESCOPE
AS-20-S — 2.5M CRYOGENICALLY COOLED IR TELESCOPE
AS-31-S — COMBINED AS-01, -03, -04, -05-S
AS-41-S — SCHWARTZSCHILD CAMERA
AS-42-S — FAR UV ELECTRONOGRAPHIC SCHMIDT CAMERA/SPECTROGRAPH
AS-43-S — UCB BLACK BRANT PAYLOAD
AS-44-S — XUV CONCENTRATOR/DETECTOR
AS-45-S — PROPORTIONAL COUNTER ARRAY
AS-46-S — WISCONSIN UV PHOTOMETRY EXPERIMENT
AS-47-S — ATTACHED FAR IR SPECTROMETER
AS-48-S — ARIES/SHUTTLE UV TELESCOPE
AS-49-S — FIRST UCB BLACK BRANT PAYLOAD
AS-50-S — COMBINED UV/XUV MEASUREMENTS (AS-04-S, 10-S)
AS-51-S — COMBINED IR PAYLOAD (AS-01-S, 15-S)
AS-54-S — COMBINED UV PAYLOAD (AS-03-S, 04-S)
AS-61-S — ATTACHED FAR IR PHOTOMETER (WIDE FOV)
AS-62-S — COSMIC BACKGROUND ANISOTROPY
AS-01-R — LST REVISIT

HIGH ENERGY ASTROPHYSICS

*HE-11-S — X-RAY ANGULAR STRUCTURE
HE-12-S — HIGH INCLINATION COSMIC RAY SURVEY
HE-13-S — X-RAY/GAMMA RAY PALLET
HE-14-S — GAMMA RAY PALLET
*HE-15-S — MAGNETIC SPECTROMETER
HE-16-S — HIGH ENERGY GAMMA-RAY SURVEY
HE-17-S — HIGH ENERGY COSMIC RAY STUDY
HE-18-S — GAMMA-RAY PHOTOMETRIC STUDIES
HE-19-S — LOW ENERGY X-RAY TELESCOPE
HE-20-S — HIGH RESOLUTION X-RAY TELESCOPE
HE-03-R — EXTENDED X-RAY SURVEY REVISIT
HE-11-R — LARGE HIGH ENERGY OBSERVATORY D REVISIT

SOLAR PHYSICS

*SO-01-S — DEDICATED SOLAR SORTIE MISSION (DSSM)
*SO-11-S — SOLAR FINE POINTING PAYLOAD
SO-12-S — ATM SPACELAB

ATMOSPHERIC AND SPACE PHYSICS

*AP-06-S — ATMOSPHERIC, MAGNETOSPHERIC, AND PLASMAS IN SPACE (AMPS)

EARTH OBSERVATIONS

*EO-01-S — ZERO-g CLOUD PHYSICS LABORATORY
*EO-05-S — SHUTTLE IMAGING MICROWAVE SYS. (SIMS)
*EO-06-S — SCANNING SPECTRORADIOMETER
EO-07-S — ACTIVE OPTICAL SCATTEROMETER

*REQUIREMENTS DEFINED TO LEVEL B (30 PAYLOADS)

Table 5. SPDA Sortie Payloads (Cont'd)

EARTH AND OCEAN PHYSICS

*OP-02-S – MULTIFREQUENCY RADAR LAND IMAGERY
*OP-03-S – MULTIFREQUENCY DUAL POLARIZED MICROWAVE RADIOMETRY
*OP-04-S – MICROWAVE SCATTEROMETER
*OP-05-S – MULTISPECTRAL SCANNING IMAGERY
*OP-06-S – COMBINED LASER EXPERIMENT

SPACE PROCESING APPLICATIONS

*SP-01-S – SPA NO. 1 – BIOLOGICAL (MANNED)
SP-02-S – SPA NO. 2 – FURNACE (MANNED)
SP-03-S – SPA NO. 3 – LEVITATION (MANNED)
SP-04-S – SPA NO. 4 – GEN. PURPOSE (MANNED)
SP-05-S – SPA NO. 5 – DEDICATED (MANNED) (B+F+L+G+C)
SP-12-S – SPA NO. 12 – AUTO. FURNACE
SP-13-S – SPA NO. 13 – AUTO. LEVIATION
*SP-14-S – SPA NO. 14 – MANNED AND AUTOMATED
*SP-15-S – SPA NO. 15 – AUTOMATED FURNACE/ LEVIATION
SP-16-S – SPA NO. 16 – BIOLOGICAL/GENERAL (MANNED)
SP-19-S – SPA NO. 19 – BIOLOGICAL AND AUTOMATED
SP-21-S – SPA NO. 21 – MINIMUM BIOLOGICAL
SP-22-S – SPA NO. 22 – MINIMUM FURNACE (MANNED)
SP-23-S – SPA NO. 23 – MINIMUM GENERAL
SP-24-S – SPA. NO. 24 – MINIMUM LEVIATION (MANNED)

LIFE SCIENCES

*LS-04-S – FREE FLYING TELEOPERATOR
*LS-09-S – LIFE SCIENCES SHUTTLE LABORATORY
*LS-10-S – LIFE SCIENCE CARRY-ON LABORATORIES

SPACE TECHNOLOGY

ST-04-S – WALL-LESS CHEMISTRY + MOLECULAR BEAM (FACIL. NO. 1)
ST-05-S – SUPERFLUID He + PARTICLE/DROP POSITIONING (FACIL. NO. 2)
ST-06-S – FLUID PHYSICS + HEAT TRANSFER (FACIL. NO. 3)
ST-07-S – NEUTRAL BEAM PHYSICS (FACIL. NO. 4)
*ST-08-S – INTEGRATED REAL TIME CONTAMINATION MONITOR
ST-09-S – CONTROLLED CONTAMINATION RELEASE
ST-21-S – LASER INFORMATION/DATA TRANSMISSION
ST-12-S – ENTRY TECHNOLOGY
ST-13-S – WAKE SHIELD INVESTIGATION
*ST-21-S – ATL P/L NO. 2 (MODULE + PALLET)
*ST-22-S – ATL P/L NO. 3 (MODULE + PALLET)
*ST-23-S – ATL P/L NO. 5 (PALLET ONLY)

COMMUNICATIONS AND NAVIGATION

*CN-04-S – TERRESTRIAL SOURCES OF NOISE + INTERFERENCE
*CN-05-S – LASER COMMUNICATION EXPERIMENTATION
CN-06-S – COMMUNICATION RELAY TESTS
CN-07-S – LARGE REFLECTOR DEPLOYMENT
CN-08-S – OPEN TRAVELING WAVE TUBE
CN-11-S – STARS & PADS EXPERIMENTATION
CN-12-S – INTERFEROMETRIC NAVIGATION & SURVEILLANCE TECHNIQUES
CN-13-S – SHUTTLE NAVIGATION VIA GEOSYNCHRONOUS SATELLITE

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*REQUIREMENTS DEFINED TO LEVEL B (30 PAYLOADS)

Table 6. Categories of Advanced Technology Requirements

Category No.	Category Name	No. of Items in Category
1	Collectors	8
2	Sensors	28
3	Generators	1
4	Systems	5
5	Special Devices	5
6	Inertial/Electromechanical	1
7	Life Sciences	4
8	Contamination	4
9	Structural & Spacecraft/ Mechanical	11
10	Environmental Control	2
11	Environmental Protection	1
12	Cryogenic Control	2
13	GN&C	2
14	Propulsion	2
15	Attitude Control/Measurement	2
16	TT&C/Data	2
17	Electrical Power	2
18	Instrument Electronics	3
19	Software	6

Item Sequence
Category
Contractor Assignment (C-Convair; GE-General Electric; RI-Rockwell)

DEFINITION OF TECHNOLOGY REQUIREMENT NO. X-Y.Z

1. TECHNOLOGY REQUIREMENT (TITLE): Descriptive title PAGE 1 OF ___

2. TECHNOLOGY CATEGORY: Technology category used in study (see Table 1).

3. OBJECTIVE/ADVANCEMENT REQUIRED: A brief statement of objective and advancement required.

4. CURRENT STATE OF ART: A brief statement of the current state-of-the-art that most nearly fits objective stated in Para. 3.

HAS BEEN CARRIED TO LEVEL ___
(See Para. 15 for number)

5. DESCRIPTION OF TECHNOLOGY

A discussion of the required advancement containing a quantitative description of the critical parameters and comparison with the current state-of-the-art.

INSTRUCTION SHEET

(NASA program development phase)
P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a) Summarizes the analyses of payload advanced technology requirements and gives the rationale for selection of the values of the critical parameters which drive the technology.

b) Identifies the benefitting payloads by number and name if space permits or by general classification if the list is lengthy.

c) Provides justification for the advancement by quantitatively describing, if possible, the payload enhancement in terms of improved mission, payload, or equipment performance, improved reliability, longer lifetime, etc.

d) State the level of technological maturity required to make it acceptable for this intended use. (See Para. 15). Give a verbal description of what is to be done within the selected level.

(See Para. 15 for number)
TO BE CARRIED TO LEVEL ___

Figure 11. Instructions for "Definition of Technology Requirements"

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.
1. TECHNOLOGY REQUIREMENT(TITLE): ______________________	PAGE 2 OF __

7. TECHNOLOGY OPTIONS:

Describes potential "spectrum" of technology and discusses how quantitative variation in the critical parameters affects the payload.

INSTRUCTION SHEET

8. TECHNICAL PROBLEMS:

Identify potential problems in advancing the state-of-the-art.

9. POTENTIAL ALTERNATIVES:

Identify any alternatives to the described technology.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Identifies, for reference purposes, on-going or planned technology programs which are closely related to the described requirements. Identifies with RTOP number, if a NASA program.

Unperturbed technology advancement is the state-of-the-art at the need date if NASA expends no special effort in this area. (See para. 13 for need date)

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS: (See Para. 15 for number)

Describes requirements for other technologies which may be necessary for the success of the stated requirement. Describes the relationship.

Figure 11. Instructions for "Definition of Technology Requirement" (Cont'd.)

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): ____________ PAGE 3 OF ___

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY 1. Analysis/Design 2. Fabrication 3. Test 4. Documentation 5.	List of key steps and time span in "waterfall" manner leading to achievement of desired technology. TYPICAL (be specific as required)																		
APPLICATION 1. Design (Ph. C) 2. Devl/Fab (Ph. D) 3. Operations 4.	Show payload development schedule which drives technology need date.																		

13. USAGE SCHEDULE:

		TOTAL
TECHNOLOGY NEED DATE	Show need date - allows for flight hardware lead time.	
NUMBER OF LAUNCHES	Number of launches each year using technology.	

14. REFERENCES:

Lists data sources and references where further information may be obtained. Includes significant contributors during user/manufacturer review.

INSTRUCTION SHEET

Definition of levels to be applied in paragraphs 4, 6 and 10.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

Figure 11. Instructions for "Definition of Technology Requirement" (Cont'd.)

Table 7. Accounting of Technology Item Sequence Numbers Not Appearing in Definition of Requirements

Item No.	Comments
C-1.3	Combined with C-1.2 because of common requirement.
RI-5.5/5.6	Data system operating in plasma- Advancement initially required was identified to be to reduce effects of boom mounted in stitu data system on the plasma. It was found to be within state of the art and dropped.
RI10.2	Gravity Gradiometer - Environment Control - Initial requirement was based on a concept by JPL that required temp. control to 0.001C. Hughes concept indicates temperature effect (low frequency effects) could be subtracted from the data.
RI-10.3	Reidentified as C-7.1, change of category.
RI-12.3/12.4	Combined with RI-12.2 because of common requirements.
RI-13.3	Reidentified as RI-2.26, change of category.
GE-15.2/15.3/15.4	Combined with GE-15.1, because of common requirements.
GE-16.2/16.3	Data display for monitor application - Advancement initially required was identified to be increased display size and improved resolution. It was found to be adequately covered within the current technology and was dropped.
GE-16.5	Combined with GE-2.6 because of closely related requirements.
GE-17.2/17.3	Combined with GE-17.1 because of related requirements.
GE-17.5	Combined with GE-17.4 because of related requirements.
C-18.3/18.4	Combined with C-18.1 because of related requirements.

Table 8. List of Symbols Used in the Definition Forms

C	-	Convair
GE	-	General Electric
RI	-	Rockwell International
AS	-	Astronomy
HE	-	High Energy Astrophysics
SO	-	Solar Physics
AP	-	Atmospheric and Space Physics
EO	-	Earth Observations
OP	-	Earth and Ocean Physics
SP	-	Space Processing Applications
LS	-	Life Sciences
ST	-	Space Technology
PL	-	Planetary
CN	-	Communications/Navigation
LU	-	Lunar

Table 9. Location of "Definition of Technology Requirement" by Category

Category No.	Category Name	Page
1	Collectors	7-13
2	Sensors	7-55
3	Generators	7-189
4	Systems	7-195
5	Special Devices	7-217
6	Inertial/Electromechanical	7-241
7	Life Sciences	7-247
8	Contamination	7-265
9	Structural & Spacecraft Mech.	7-293
10	Environmental Control	7-341
11	Environmental Protection	7-351
12	Cryogenic Control	7-355
13	GN&C	7-365
14	Propulsion	7-375
15	Attitude Control/Measurement	7-385
16	TT&C/Data	7-393
17	Electrical Power	7-401
18	Instrument Electronics	7-409
19	Software	7-423

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.1

1. TECHNOLOGY REQUIREMENT (TITLE): Large Gamma Ray Survey Instr. PAGE 1 OF 3

Sensitivity, spatial resolution, conversion efficiency, energy resolution.

2. TECHNOLOGY CATEGORY: Collector

3. OBJECTIVE/ADVANCEMENT REQUIRED: Sensitivity of 10^{-8} photons/cm^2/sec, active collector area 3m^2 to 8m^2, angular resolution 0.1° in selected bands, 1° over 20 to 10^6 MeV, conversion efficiency 50% or better, energy resolution 10%.

4. CURRENT STATE OF ART: Current state-of-art 10^{-7} photons/cm^2/sec, active collector area 1 m^2, angular resolution 1° in balloon flight, 1/16m^2 in space flight to date.

HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY — The large gamma ray survey instrument will probably use detectors in spatial measurement compatible layers (laminates) to convert incident gamma ray energy in the range 20 to 10^6 MeV to positron-electron pairs. Subsequent layers of detectors can use charged particle detectors to resolve lower energy components. Detectors that work in the pair production region have distinct advantages such as the fact that each photon transfers most of its energy to an electron-positron pair and the electron-positron pair preserves the direction information of the photon fairly well. To date, the typical separation between the pairs is $M_e C^2/E_{photon}$ (about 0.3 deg. at 100 MeV). The actual angular resolution will be limited by the multiple scattering of the electron-positron pairs (1 deg. achieved to date). Rejection of charged particles flux is important since number of charged particles during part of observation orbit may exceed the gamma ray flux up to 1000 times.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B

6. RATIONALE AND ANALYSIS:

a. Trades in effective area, sensitivity/unit area, energy resolution, angular sensitivity, field of view, and degree of rejection of charged particles lead to a compromise. Components involved include a surrounding (usually) plastic scintillator which provides anti-coincidence vetoes, a converter sandwich that produces sufficient radiation length to cause pair production, intermediate sandwiches or spatial detectors for track location, and energy discriminators at the bottom to measure energy of incident photons (or components at lower energies). Discrimination data are recorded to identify charged par-particles, or neutral primaries as well as gamma rays where anti-coincidence methods fail. Auxiliary measurements of shower development, secondary containment, and response of anticoincidence guard counters enable estimates of what fraction of output is due to freak events.

b. Two payloads HE-16-S (1981), High Energy Gamma Ray Survey and HE-08-A, Large High Energy Observatory A (Gamma Ray), 1986, benefit from development of capability.

c. The instrument will perform in sortie and automated missions to give a full sky survey with a sensitivity and resolution factor of 10 better than previously accomplished. (Final Report, High Energy Astrophysics Working Group Report, May 1973).

d. Smaller gamma ray instruments (OSO III Gamma Ray Detector, Cornell University), photographic spark chamber telescope for balloon use, and the Goddard Digitized Spark Chamber Gamma Ray Telescope indicate current state-of-art (10^{-6} to 10^{-7} photons/cm/sec). When 10^{-8} photons/cm/sec sensitivity with 8m^2 effective area has been achieved (by 1981), above technology requirement is satisified. Testing on a shuttle sortie flight is expected prior to longer term automated flight.

TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. C-1.1

1. TECHNOLOGY REQUIREMENT(TITLE): Large Gamma Ray Survey Instrument — PAGE 2 OF 3

Sensitivity, spatial resolution, conversion efficiency, energy resolution.

7. TECHNOLOGY OPTIONS: Extended area (8 m^2) versions of previous high energy gamma ray detectors previously used are possible. Option A uses a surrounding plastic anticoincidence scintillator, a CsI/plastic converter sandwich, a Cerenkov counter section, and an energy discriminator using NaI, tungsten and plastic layers. Option B consists of a spark chamber surrounded by anticoincidence scintillators. Two spark chamber gaps are used below a top anticoincidence scintillator to classify the incoming primary which then passes to a one radiation length converter (lead or equiv.) followed by a plastic scintillator. Up to 12 spark chamber gaps detect the pairs or secondaries when fired by a triggered pulse. A final plastic layer is used for coincidence-anticoincidence triggers. There is a trade between high efficiency of conversion versus angular resolution. Option C uses thin nuclear emulsion or plastic stacks interspersed with spark chamber plates.

8. TECHNICAL PROBLEMS: (1) Gamma ray detectors in the spectral region from 20 MeV to 1000 MeV are subject to smearing of angular resolution by multiple Coulomb scattering (scattering angle approximately proportional to 1/E). Efforts have been made to use fairly numerous thin conversion plates distributed over many gaps of a spark chamber or equivalent detector. Anticoincidence rejection/acceptance levels may result in overloading or conversely in excessive dead time. Dimensional resolution and stability affect angular measurements resolution in all cases of large detector arrays. (2) Energy resolution and accuracy requires depth in scintillator materials, hence increased weight. (3) Actual angular resolution and energy resolution achieved will be a compromise vs allowable weight.

9. POTENTIAL ALTERNATIVES: Track measuring devices consisting of layers of detector material with resistive readout or in terms of differences in time to locate an event are being considered in lieu of spark chambers with arrays of photomultipliers, image devices, photographic cameras. Spatial detection can be improved by use of a large number of thin plates; however, energy resolution can be improved by long hexagonal segments glued together in the desired area array. Each hexagonal segment could have a hexagonal photomultiplier.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. RTOP W74-70649 (188-46-57), Gamma Ray Astronomy, Albert G. Opp (202) 755-3665.

b. RTOP W74-70650 (188-46-57), Gamma Ray Astronomy, C. R. Fichtel (301) 982-6281.

c. RTOP W74-70651 (188-46-64), Astrophysical Investigations on the Space Shuttle, Albert G. Opp (202) 755-3665.

d. RTOP W74-652 (188-64-64), Shuttle Definition Studies for High Energy, F. B. McDonald.

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

a. C-29, C-93 Protective shell/cover to enable holding of internal temperature to ± 2°K of a selected temperature between 283°K and 303°K, cleanliness to class 1000, pressurization to one atmosphere, minimum gamma ray attenuation (20 to 10^6 MeV) with minimum protective shell secondaries, $Z < 20$.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-1.1

1. TECHNOLOGY REQUIREMENT (TITLE): Large Gamma Ray Survey Instrument PAGE 3 OF 3

Sensitivity, spatial resolution, conversion efficiency, energy resolution

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Options & Trade Anal.	—																		
2. Prototype Des. & Fab.		—																	
3. Test & Evaluation			—																
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)				G1			G2												
2. Devl/Fab (Ph. D)						G1				G2									
3. Operations							● G1		● G1				● G2			G2			
4. Information Use							—		—					—	—	—			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				G1			G2											
NUMBER OF LAUNCHES							G1		G1			G2	G1					4

14. REFERENCES:

a. Summarized NASA Payload Descriptions, Sortie Payloads, PD, NASA, July 1974, pages 106-107.
b. Summarized NASA Payload Descriptions, pages 50, 51.
c. Payload Descriptions, Vol. I, Automated Payloads, Level B Data, July 1974.
d. Final Report of the Space Shuttle Payload Planning Working Groups, High Energy Astrophysics, NASA/GSFC, May 1973, pages 38 and A-19.
e. RTOP Plan Summary, FY 1974, NASA, page 104.
f. NASA SP-243, Introduction to Experimental Techniques of High Energy Astrophysics, H. Ogelman and J. R. Wayland, GSFC, 1970, pages 95-122.
g. Conference, Bob Hartman and E. S. Saari at GSFC, 10 Sept. 1974.

Legend
G1 = Prototype Sortie Mission Instrument
G2 = Automated (free flyer) Instrument

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.2

1. TECHNOLOGY REQUIREMENT (TITLE): X-ray Telescope PAGE 1 OF 5

Development of better sensitivity, spatial resolution and field of view.

2. TECHNOLOGY CATEGORY: Collectors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Improve sensitivity to enable detection of X-ray sources to 10^{-8} Sco X-1, angular resolution to 0.5 arcsec over a FOV of 512 arcsec (with extension of FOV at 5 arcsec resolution to 18,000 arc secs for a widefield version telescope).

4. CURRENT STATE OF ART: Angular resolution to 2.5 arcsec over a 540 arc sec field has been achieved; field extension at about 5 arc sec resolution was possible out to FOV of 1800 arcsec. HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY - Techniques are needed to develop X-ray mirrors and structures enabling confocal nested mirrors to achieve an effective collector area of 5000 cm^2 with an angular resolution of 0.5 arcsec over a field of at least 512 arcsec in the 0.03 to 4 keV energy range. Current concepts considered for extension to the larger telescope include a system with two sets of about 5 concentric mirrors nested around a common axis. The input set usually consists of cylindrical shells modified by grinding and polishing to a paraboloidal cross section. The paraboloidal set of mirrors passes the X-rays to a second set of cylindrical mirrors modified to a hyperboloidal cross section which focuses the X-rays onto an image plane. Previous smaller mirrors have been made of fused silica and also Kanigan (nickel) on a metal substrate. (The Baez alternative technique uses crossed arrays of flat plates bent to hyperboloid and paraboloid contours, but Baez configurations cannot readily achieve the desired resolution.) A three geometric element glancing incidence X-ray telescope (Patent No. 3,821,556 by Richard B. Hoover) option is available but requires much larger geometry for same sensitivity.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Effective area and mass of mirror segments used in the concentric configurations depend upon selection of materials and thickness of the surfaces (or shells) necessary to maintain the desired contour accuracy. Preliminary trades between glasses, fused silica, metal, and early composites indicate potential success of large X-ray telescope collector areas with limited weight. Further investigation is recommended for mirrors of temperature insensitive laminates coated at the X-ray collecting surfaces with X-ray energy range compatible materials polishable to very fine smoothness. A goal of 500 to 1000 kg per 1000 cm^2 of effective collector area appears feasible.

b. Present long term plans appear to indicate a progressive growth in collector area, resolution, and angular field of view beginning with HEAO-B (300 cm^2) in 1978, benefiting a wide field HE-03-A (400 cm^2) telescope in 1982, a narrow field HE-11-A 1.2 M (1000 cm^2) telescope in 1983, and finally, the HE-01-A Large X-ray Telescope Facility in 1986.

c. The high resolution large collector area X-ray telescope capability is justifiable on the basis of improved imaging capability enabling detailed study of sources in the range 10^{-4} Sco X-1 to 10^{-8} Sco X-1 ($\sim 10^{-15}$ ergs/cm^2/sec). (Ref. pages 31, 32, Vol. 3, Final Report of Space Shuttle Payload Planning Group, May 1973).

d. Smaller X-ray telescopes built from concentric mirror concepts have been tested and utilized for imaging but need for lighter weight for larger telescopes poses some problem. The aerospace industry is currently developing light weight temperature insensitive materials which may be applicable in assembly of large X-ray telescopes. Technology satisfied when light weight prototype of >5000 cm^2 effective area high resolution telescope is built and tested in space.

TO BE CARRIED TO LEVEL 8

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1. TECHNOLOGY REQUIREMENT(TITLE): X-ray Telescope PAGE 2 OF 5

Sensitivity, spatial resolution, and field of view.

7. TECHNOLOGY OPTIONS: Choice of an energy range and a compatible material fixes the X-ray focal ratio. For most efficient X-ray collector optics, one should optimize the collecting area by trades between the surface material high energy limit and the maximum attainable area. The geometric area, A, of an X-ray telescope is ≈

$$\pi \left(\frac{D}{2}\right)^2 \left(\frac{L}{4F}\right)$$

where L = length of each X-ray mirror set, D = concentric mirror diameter, and F = focal length. The effective area can be increased by nesting additional surfaces, but all collector surfaces need to be kept confocal. Besides choice of material, diameter, number of mirrors, mirror thickness, and focal length, the shuttle bay dimensions needed to be considered.

(See pages 4 and 5 for more description.)

8. TECHNICAL PROBLEMS: The combined performance of the mirror segments in collecting and focusing X-rays in compliance with ideal equations or telescope configuration is affected by dimensional stability, adjustability of the elements, as well as their relative alignment. For larger telescopes, there is difficulty in obtaining thin materials with good X-ray reflection characteristics that are also temperature insensitive. Consequently, thermal control to tight tolerances such as 273 ± 1°K, may be required.

9. POTENTIAL ALTERNATIVES: There appear to be no better alternates.

a. Large area proportional counter arrays with accurate time difference analysis and readout may produce signals which, with considerable data processing, might reach sensitivities and angular resolution of a grazing incidence telescope.
b. Multilayer spatial detectors of large area. (High angular resolution is unlikely.)
c. Proportional counters with long modulation collimators and mechanical scanning. (However, geometry for high resolution is prohibitively large.)

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. RTOP: W74-70631, X-ray Astronomy, N. G. Roman.
b. HEAO-B 0.815 m X-ray telescope, R. Giacooni, ASE.
c. Additional X-ray telescopes gradually improved in collector area, sensitivity, angular resolution, and stability need to be funded as necessary technology development steps to enable attainment of techniques, materials and structures for Large X-ray Telescope Facility.

EXPECTED UNPERTURBED LEVEL 7

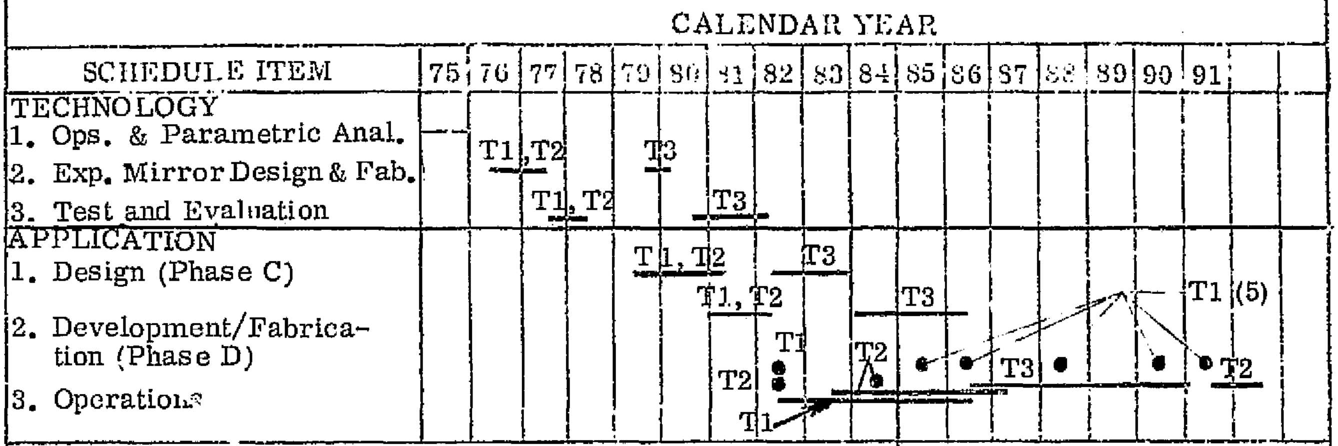
11. RELATED TECHNOLOGY REQUIREMENTS: According to R. Giacconi, stabilized images with X-ray optics and sensors can be obtained to desired tolerances if adequate UV aspect optics, guide star trackers, and a field monitor camera are utilized. Besides providing guide star tracker error signals for pointing and stabilizing the X-ray telescope, corrective high frequency error signals can be applied to an X-ray converter/intensifier to minimize high frequency jitter components in the output image (or to correct the image during ground data processing, since any modern X-ray imaging device provides accurate times of arrival of individual photons).

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.2

1. TECHNOLOGY REQUIREMENT (TITLE): X-ray Telescope PAGE 3 OF 5

Sensitivity, angular resolution, field of view

12. TECHNOLOGY REQUIREMENTS SCHEDULE:



13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	Total
TECHNOLOGY NEED DATE					T 1 T 2			T3										Total
NUMBER OF LAUNCHES								T 1 T 2	T 2	T 2	T 1	T 1 T 3		T 1		T 1	T 1 T 2	11

14. REFERENCES:

a. Final Report of the Space Shuttle Payload Planning Working Groups, NASA/GSFC, May 1973, pages A-1, -2, A-4.

b. Summarized NASA Payload Descriptions, Sortie Payloads, PD, NASA, July 1974, pages 112, 113, 114.

c. Payload Descriptions, Vol. I, Automated Payloads, Level B Data, NASA, July 1974, HE-03-A, HE-11-A, HE-01-A; pages 2-31 thru 2-56, 2-131 thru 2-158, and 2-1 thru 2-28.

d. U.S. Patent 3,821,556, Three Mirror Glancing Incidence System for X-ray Telescope, Richard B. Hoover, Huntsville, Ala.

LEGEND

● Sortie operations

—— Automated operations

(T 1)=HE-03-A, 0.75 m X-ray Telescope (82-A), (85, 86, 88, 90, 91 - S).
(T 2)=HE-11-A, 1.2 m X-ray Telescope (82, 84 - S), (83, 91 - A).
(T 3)=HE-01-A, Large X-ray Telescope Facility (1986).

S = Sortie
A = Automated (free flyer)

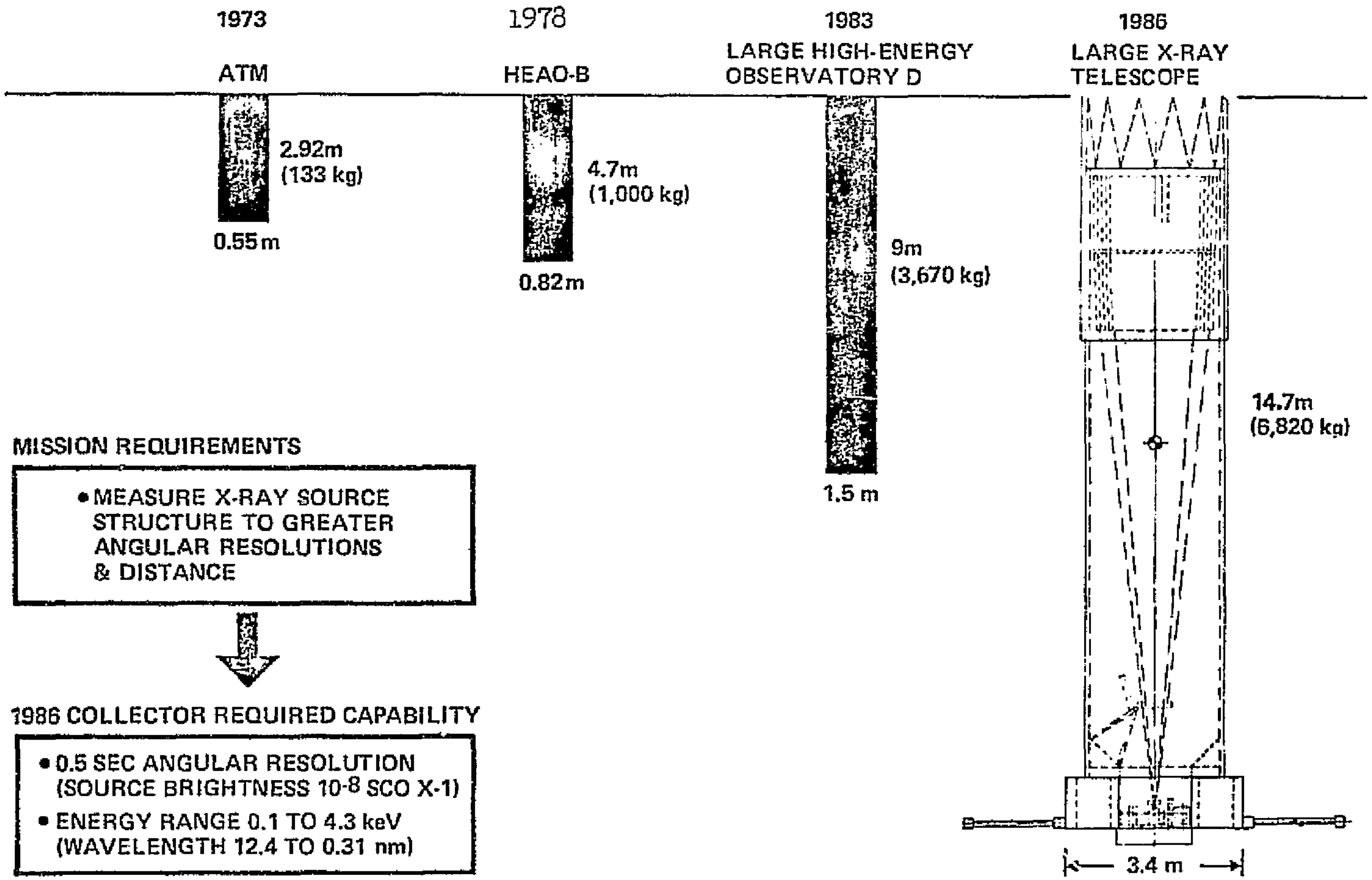
15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

1. TECHNOLOGY REQUIREMENT (TITLE): X-ray Telescope PAGE 4 OF 5

Development of better sensitivity, spatial resolution and field of view

COLLECTOR REQUIREMENTS
X-RAY TELESCOPES



Development of better sensitivity, spatial resolution and field of view

TECHNOLOGY NEEDS
X-RAY TELESCOPE

CATEGORY	REQUIRED CAPABILITY		STATE OF ART	
	1983	1986	1973	1978
WAVELENGTH (nm)	12.4 - 0.31	12.4 - 0.31	3.3 - 0.5	12.4 - 0.4
ANGULAR RESOLUTION (SEC)	0.5	0.5	3	2
EFFECTIVE COLLECTOR AREA (CM^2)	500	5,000	42	400
SENSITIVITY, SCO X-1	10^{-7}	10^{-8}	5×10^{-6}	5×10^{-7}
MIRROR SLOPE ERROR (ARC SEC)	0.1	0.1	0.5	0.35
DIAMETER (m)	1.2	3	0.4	0.8

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.4

1. TECHNOLOGY REQUIREMENT (TITLE): Optical Telescopes PAGE 1 OF 8
Mirror figure accuracy; efficiency in far UV; stray light control

2. TECHNOLOGY CATEGORY: Collectors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development of optical telescope figure accuracy to $1/50\lambda$ * for 1 to 3m primary and $1/70\lambda$ * for secondary to achieve $<0.05\lambda$ total system wavefront error and <1% scattering from 90 to 5000 nm.

4. CURRENT STATE OF ART: A 1.8m mirror has been configured to $1/62\lambda$ rms; telescope mirror surfaces up to 1m dia. have been polished to a smoothness of 2 nm peak to valley yielding less than 3% scatter at 120nm (UV) but with $1/20\lambda$ rms figure error.
HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY

Although mirrors have been configured to $1/62\lambda$ (1.8m) at Itek and $1/10\lambda$ (3.8m) at 632.8 nm at AURA in the laboratory for ground telescope use, the largest mirror operable at UV wavelengths in space was 0.81m. Mirror surface contour is dependent upon choice of material, thermal coefficient of expansion, the combination of effects of shaping, grinding, polishing, and coating processes, as well as figure sensing (interferometer) capabilities and the environment maintained during manufacture, assembly, test, launch, and operation. For the telescope mirror, compensation for errors in the primary by pregrinding calculations or by match figuring the secondary (Ritchey Chrétien conf.) helps, but shop, laboratory, and assembly test equipment for future telescopes need to be designed and improved to enable total system measurements as well as component measurements.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☒ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. The manufacture of mirrors to date has been limited by the ability to measure surfaces during the course of manufacture as well as by ability to maintain an optimum "finishing" environment. Stable metering structures are needed during final matching of Ritchey Chrétien mirrors as well as during observations in space. A key item in the process is a mirror scanning interferometer to periodically measure mirror surface contours to at least $1/100\lambda$ with automatic reduction of system and surface wavefront contour plots. Techniques are needed to separate contour and surface errors as well as alignment and focus errors in matching Ritchey Chrétien type mirrors.

b. Although AS-01-A, Large Space Telescope, benefits mostly from the improvement in optical telescope technology, other payloads such as AS-14-A, 1m UV-Optical Telescope; AS-04-S, 1m Diffraction Limited UV-Optical Telescope; AS-31-S, Combined AS-01, -03, -04, -05-S; and AS-51-S, Combined IR Payload (AS-01, -15-S) will also benefit from better contours and super polishing.

c. The better contours and super finishes will improve far UV (200 to 90 nm) reflection efficiency, angular resolution, and minimize light scatter (diffuse reflections from mirror surfaces). Hence, full angular resolution as well as sensitivity of the telescope may be achieved. The larger telescopes may approach the goal of sensing magnitude 28 stars

TO BE CARRIED TO LEVEL 8

*at 632.8 nm

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DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.4

1. TECHNOLOGY REQUIREMENT (TITLE): Optical Telescopes PAGE 2 OF 8

Mirror figure accuracy; efficiency in far UV; stray light control

6. RATIONALE AND ANALYSIS: (Cont'd)

in an exposure time of <10 hours assuming that best sensitivity sensors are used.

d. A 0.813m telescope, OAO-C, is currently in orbit but the wavefront error is larger than the technology goal.

When a total system wavefront error of $<1/20\lambda$ and less than 1% light scatter in 90 to 5000 nm spectral range has been achieved with a large telescope in an environment equivalent to that of an LST in orbit, this technology goal will have been met. Final test will be accomplished in space under gravity release conditions by means of special LST on board built in test equipment.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-1.4

1. TECHNOLOGY REQUIREMENT(TITLE): Optical Telescopes PAGE 3 OF 8

Mirror figure accuracy; efficiency in far UV; stray light control

7. TECHNOLOGY OPTIONS: The total system allowable wavefront error is a compromise between absolute focus achievable and optical system quality. Optical system quality in the extreme case of a 3 meter telescope is degraded from ideal by manufacturing error contributions (0.026λ), alignment error (0.009λ), design error (0.001λ), mirror mount distortion effects (0.01λ), focus maintenance (0.025λ), material variation (0.015λ), and thermal distortions (0.026λ). An operation effective resolution is further degraded by image motions with about 0.0025 arc secs from guide signal errors, 0.0025 arc secs from metering and mount structures. Attitude control disturbances (0.0025 arc sec) and vehicle vibration (0.0025 arc sec) also were considered in the trades of parameters affecting resultant resolution and wavefront errors. Most current telescope concepts use secondaries with an obscuration of 0.30. Up to 0.50 has been utilized (such as in IUE where auxiliary baffles caused the obscuration problem). Thinner mirrors offer possibilities for continual mirror figure adjustments. Ultimately fully servoed active control telescopes may be feasible.

8. TECHNICAL PROBLEMS:

a. UV Efficiency. The major problem for 3m LST optics involves degradation of UV efficiency and low reflection losses. Besides low wavefront errors (1/7 to $1/10\lambda$ between 90 and 150 nm), super finishes down to 1 nm are desired. Even with these, interference phenomena of coatings in the 90 to 120 nm regions will be difficult to overcome.

b. Mirror mounting.

c. Automated feed techniques may be needed in coating processes to enable super finishes.

d. Dust particles need to be avoided in final finishing.

e. Stray light scatter.

9. POTENTIAL ALTERNATIVES: If mirror weight and dimensional stability problems occur due to potential shuttle load or environmental limits, light weight mirrors made of ultrastable laminates surfaced with smoothable reflecting materials may be necessary. However, insufficient research experience exists to apply these techniques to large telescopes at this time. An effort is needed to obtain interference-free coatings for mirrors in 90 to 150 nm region. Mirror coatings may be protected by an easily removed layer of material to avoid dust particles and contamination damage. Coatings applied in space may be necessary to avoid some contamination problem.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. W-74-70265 (502-21-32), Optical Contamination of Spacecraft, Hoyt Weathers, MSFC.

b. W-74-70658 (188-78-56), Design, Analysis and Evaluation of LST Instrument Systems, GSFC.

c. W-74-70661 (188-78-57), Large Space Telescope Advanced Technology, G. Emanuel, MSFC.

d. W-74-70662 (188-78-58), Large Space Telescope Phase B Studies, J. Downey, MSFC.

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS: Besides improved figure accuracy and far UV efficiency, related developments are desired in guide star tracking, instrument mounting, and materials selection. To enable better weight control as well as

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.4

1. TECHNOLOGY REQUIREMENT (TITLE): Optical Telescopes PAGE 4 OF 8

Mirror figure accuracy; efficiency in far UV; stray light control

11. RELATED TECHNOLOGY REQUIREMENTS: (Cont'd)

performance; greater development and use of light weight, stiff, vibration absorbent, temperature insensitive, metering mount, and instrument structures may be necessary. Contamination measurement and control continues to be a major problem.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. C-1.4

1. TECHNOLOGY REQUIREMENT (TITLE): Optical Telescopes — PAGE 5 OF 8

Mirror figure accuracy; efficiency in far UV; stray light control

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Concepts Analysis																			
2. Techniques Development																			
3. Test & Evaluation																			
4.																			
5.																			
APPLICATION																			
1. Design (Phase C)			TA																
2. Devl/Fab (Phase D)				TA															
3. Operations:								TL			TL					TL			
							T1		T2										
					T3			T4											

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE			TA															
NUMBER OF LAUNCHES					2	2	1	4	5	4	5	6	6	5	6	6		52(1)

14. REFERENCES:

a. Final Report of Space Shuttle Payload Planning Working Groups, Vol. I, Astronomy, pages 4-6.

b. Large Space Telescope Phase A Final Report, TMX-64716, NASA/MSFC, December 15, 1972.

(References continued on Page 6.)

Legend:

- ● = Sortie Operations
- — = Automated Operations
- TA = Optical Telescope Assembly, AS-01-A, Large Space Telescope
- TL = Integrated Telescope, AS-01-A
- T1 = AS-14-A, 1 m UV-Optical Telescope
- T2 = AS-04-S, 1 m Diffraction Limited UV-Optical Telescope
- T3 = AS-31-S, Combined AS-01, -03, -04, -05-S
- T4 = AS-51-S, Combined IR Payload (AS-01, -15-S)
- (1) = Does not include up to 9 service missions for AS-01-A.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.4

1. TECHNOLOGY REQUIREMENT (TITLE): Optical Telescopes PAGE 6 OF 8

Mirror figure accuracy; efficiency in far UV; stray light control

c. Large Space Telescope, Optical Telescope Assembly/Scientific Instruments, Phase B Definition Study Monthly Progress Reports, Sept. 1973 to Aug. 1974.

d. Summarized NASA Payload Descriptions, Level A Data, PD, NASA, July 1974, pages 22, 23.

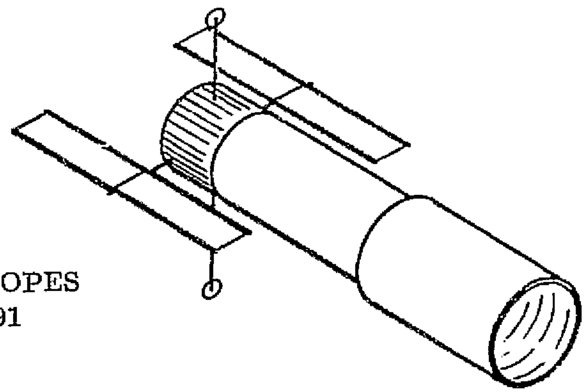
c. Preliminary Payload Descriptions, Vol. I, Level B Data, NASA, July 1974, pages 1-1 thru 1-23.

d. Comments, Garvin Emanuel, 6 Jan. 1975.

Mirror figure accuracy; efficiency in far UV; stray light control

COLLECTOR REQUIREMENTS

Telescope, UV-IR



LARGE
TELESCOPES
1980-1991

SPECIFIC MISSION REQUIREMENTS	REQUIRED COLLECTOR CAPABILITY
IMPROVE FAINT OBJECT DETECTION & SPECTRAL MEASUREMENTS OBTAIN DIFFRACTION-LIMITED IMAGING	TOTAL SYSTEM WAVEFRONT ERROR $\leq \lambda/20$ SPECTRAL RANGE 90 TO 5,000 NANOMETERS UP TO 7.1 m^2 COLLECTOR AREA (3m dia.)

TECHNOLOGY NEEDS
Telescope, UV-IR

CATEGORY	REQUIRED CAPABILITY	STATE OF ART
MIRROR FIGURE ERRORS		
PRIMARY	$\leq 1/50\ \lambda$, 1 TO 3m DIA.	$1/20\ \lambda$ (1 m DIAMETER)
SECONDARY	$\leq 1/70\ \lambda$, $\approx$ 1m DIA. AT 632.8 nm	$1/20\ \lambda$ (1 m DIAMETER) (Better than 1/20 with smaller secondaries)
SPECTRAL RESPONSE	90 TO 5,000 nm	CERTAIN RANGES ONLY
IMAGE MOTION	$\leq$0.005 ARC-SEC	0.1 ARC-SEC
MIRROR SURFACE SCATTERED LIGHT	$\leq$1%	3 to 10%

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.5

1. TECHNOLOGY REQUIREMENT (TITLE): Infrared Telescopes; PAGE 1 OF 7
Sensitivity improvement; minimization of local flux

2. TECHNOLOGY CATEGORY: Collectors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Improve far infrared sensitivity by reducing the local IR flux to $<10^2$ photons/cm^2/sec. Desired telescope spectral bandwidth 2 to 3000 μm (for family of IR telescopes). Increase cryogenic efficiency through minimization of heat transfer ($\leq$250 joules/hr) from the ambient environment to the cryogen.

4. CURRENT STATE OF ART: a. AIRO 0.914m IR telescope local flux $< 5 \times 10^{-14}$ WHz$^{-1/2}$ delivered to detector area ~1 cm^2. b. F. Low 0.15m IR telescope cooled by LHe/LNe to about 4.2°K. Estimated local flux ~10^{-17} WHz$^{-1/2}$. Cooled military telescopes have been flown, possibly with advanced technology.

HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY The instruments of concern are to be used primarily for observations of faint cool objects in the far infrared regions beyond the solar system. Even when placed outside the influence of the earth's atmosphere, IR detectors in such a telescope receive more radiation from the instrument itself than from the astronomical objects they seek to observe. Fluctuations in local radiation set a limit in the sensitivity achievable by subtraction methods. Since the present application cannot tolerate spectral band and/or narrow FOV limitations, the background radiation itself must be minimized. The desired result can be achieved by artificial cooling, the only limiting factor being the inherent detector sensitivity. Therefore, the operating instrument temperature must be lowered sufficiently to reduce the local flux due to background noise below the equivalent noise produced by a cooled detector.

One of the telescopes required will be capable of observations over a 5 - 1000 μm spectral range, but is primarily optimized for a somewhat narrower region (e.g., 10-50 μm for the 1.5m instrument of the AS-01-S payload). Detectors having a noise-equivalent power (NEP) of 10^{-16} WHz$^{-1/2}$ in the 10-30 μm region with decreased sensitivity at longer wavelengths, are currently available. Assuming a 0.05 emissivity, a telescope would have to be cooled to below 40°K to take full advantage of this NEP in the 10-50 μm band. NEP's approaching 10^{-18} WHz$^{-1/2}$ have now been reported and no doubt will be available in the 1980's. Proper use of these devices can be made possible by a cryogenic system capable of maintaining the telescopes at less than 20°K and the detectors at the cryogen temperature $\geq$ 1.5°K, thus reducing local flux to ~10^2 photons/sec. A small telescope cooled by liquid helium (4.2°K) and liquid neon has been flown in high altitude airplanes. See pages 6 and 7 for additional description.
Possibly the military have flown telescopes with advanced technology.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) To accomplish their purpose the payload IR instruments require sufficiently high sensitivity to give them the capability to perform the proposed observations and measurements in various bands within the 2 to 3000 μm range. The greatest sensitivity can be achieved by reducing background noise below the detector noise level. The solution is to provide a cryogenic system sufficient to lower the temperature of both the detectors and the collector to make them compatible with detector capability.

TO BE CARRIED TO LEVEL 8

1. TECHNOLOGY REQUIREMENT (TITLE): Infrared Telescopes; Sensitivity improvement; minimization of local flux

6. RATIONALE AND ANALYSIS: (Cont'd)

(b) Most IR astronomy payloads can benefit from a minimization of the local IR flux. Three Sortie and two Automated payloads are identified for the period ending in 1991.

(c) The reduction or suppression of the background thermal noise can be translated directly into an enhanced ability to penetrate the far infrared regions to detect and locate very cool IR sources and to perform spectroscopy and photometry of faint or extended sources, to the limiting capabilities of the sensors.

(d) Collector areas of 10^4 cm^2 and larger with local interfering signals reduced below noise of best available detectors (10^{-16} $WHz^{-1/2}$ for $\lambda > 30$ μm and 10^{-17} $WHz^{-1/2}$ for $\lambda < 30 \mu m$). Even a 10^{-15} $WHz^{-1/2}$ would represent a significant advance. Final test of a cryogenically cooled IR telescope for astronomical use in space will be accomplished on a Shuttle Sortie flight.

Initial test would be performed in a good cooled vacuum chamber.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.5

1. TECHNOLOGY REQUIREMENT(TITLE): Infrared Telescopes; PAGE 3 OF 7

Sensitivity improvement; minimization of local flux

7. TECHNOLOGY OPTIONS:

A reduction in local background radiation may be accomplished by working either in a narrow spectral band and/or in a narrow field of view for a fixed size IR telescope. These options would defeat the purpose and the objectives of the payloads by precluding Fourier spectroscopy, broad-band photometry of extended sources, observations of faint sources, etc. Current trends indicate that the problem may be alleviated by increasing effective collector area such as in payloads AS-20-S, AS-15-S. However, an optimum compromise in collector area, telescope cooling, detector cooling, detector array area and detector sensitivity is expected to enable implementation of IR telescopes compatible with the investigator needs, shuttle accommodation capability, and the available budget for each time period.

8. TECHNICAL PROBLEMS:

a. A very cold IR telescope is susceptible to contamination in space resulting from shuttle outgassing, water vapor release, migration of sublimated materials, etc. In addition each particle floating in the near field of view of the telescope tends to act like a bright IR source tending to degrade desired astronomical source observations.

b. Since the IR telescope needs to be filled with cryogens some time before launch, the DeWar should be effective at the surface of earth as well as in space. If too much heat from the outside leaks in, more cryogen is required. Consequently, weights tend to exceed desired values due to an extremely heavy Dewar or large quantity of cryogen.

9. POTENTIAL ALTERNATIVES:

a. The improved sensitivity may be obtained by increase in collector area (such as 2.5m dia. in AS-20-S, 3m in AS-15-S) with the output coupled to cryogenically cooled instruments (detectors) to eliminate most of the local flux around the detectors.

b. Discrimination against local flux noise may be possible if heterodyne type detectors (but cryogenic) can be used to limit effective bandwidth while measuring selected IR spectral lines.

c. It is recommended that further research be accomplished in finding temperature insensitive light weight materials such as beryllium and graphite epoxies suitable for IR telescope optics, metering structure, and Dewars, compatible with cryogens ranging from LN_e to superfluid helium.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENTS.

a. RTOP 356-41-01, Development of Shuttle Infrared Telescope Facility, ARC, D. Chapman/J. V. Foster (415) 965-5065.

b. W74-70626 (188-41-55) Infrared Astronomy, N. W. Boggess, (202) 755-3688, Hqs.

c. W74-70628 (188-41-55) Infrared Astronomy, Glen Goodwin, (415) 965-5065, ARC.

d. W74-70655 (188-78-51) Low Gravity Superfluid Helium Advanced Technology Development, R. A. Potter, (205) 453-3432, MSFC.

e. Contract, Hughes Aircraft Company, awarded 1974,

f. Program Code 352, Airborne Research, R. Cameron, ARC.

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

Areas in which greater effectiveness as well as weight savings can occur in the process of minimizing IR local flux are: (a) absorption, reflectivity, and emissivity of mirror, baffle, and telescope structure surfaces visible to super cooled detector/amplifier assemblies,

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.5

1. TECHNOLOGY REQUIREMENT (TITLE): Infrared Telescopes; Sensitivity improvement; minimization of local flux

11. RELATED TECHNOLOGY REQUIREMENTS: (Cont'd)

(b) thermal control necessary to hold IR telescope and optics temperatures constant at desired values, (c) selection of effective cryogens for telescope thermal shields, (d) large aperture Dewars, contamination protection enabling maintenance of reflection and emissivity characteristics desired, alignment and adjustment of supercooled telescope optical elements.

NASA/ARC already has Phase B equivalent studies underway for system predesign, critical components for AS-01-S and AS-11-A. At present no equivalent effort is known for AS-15-S and AS-07-A. AS-20-S is an extension on up-scaling of AS-01-S but with lessons learned applied.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.5

1. TECHNOLOGY REQUIREMENT (TITLE): Infrared Telescopes; PAGE 5 OF 7

Sensitivity improvement; minimization of local flux

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Concepts & Parametric Studies	T1							T2											
2. Exper. Hardware Dev.	T1		T3							T2									
3. Test & Evaluation	T1			T3							T2								
APPLICATION																			
1. Design (Phase C)		T1			T3							T2							
2. Development/Fabrication (Phase D)					T1	T3								T2					
3. Sortie Operations					T1	o	o o	o o	o o	o o	o		o	o	o *	o *	o *	T2	
							T3	x x	x x	x	x	x	x	x	x	x	x		
4. Automated Operations						T4													
								T5											

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE		T1		T3							T2							
NUMBER OF LAUNCHES				1	2	4	5	3	6	6	4	2	5	3	5	5		56

14. REFERENCES:

a. Summarized NASA Payload Descriptions, Sortie Payloads, PD, NASA, July 1974, pp. 30, 62, 64, 78, 86.

b. Summarized NASA Payload Descriptions, Automated Payloads, PD, NASA, July 1974, pp. 26, 32.

c. Final Report of the Space Shuttle Payload Planning Working Groups, Vol. I, NASA/GSFC, May 1973, pp. 6 thru 13.

d. Reference Earth Orbital Research and Applications, Vol. II, NASA, January 1971, Section 6.

e. Instrumentation in Astronomy - II, Proceedings of the SPIE Meeting, March 1974.

Legend:

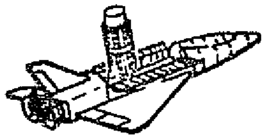
T1 - AS-01-S, 1 to 1.5m Crycgenically Cooled IR Telescope
T2 - AS-20-S, 2 to 2.5m Cryogenically Cooled IR Telescope
T3 - AS-15-S, 3m Ambient Temperature Telescope (Alternate)
T4 - Automated IR Telescope Missions (AS-11-A)
T5 - AS-07-A, 3m Ambient Temperature IR Telescope

15. LEVEL OF STATE OF ART

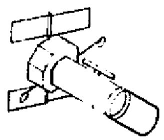
1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

Sensitivity improvement; minimization of local flux

COLLECTOR REQUIREMENTS – CRYO-COOLED IR TELESCOPES



1980
1 m CRYO-COOLED TELESCOPES



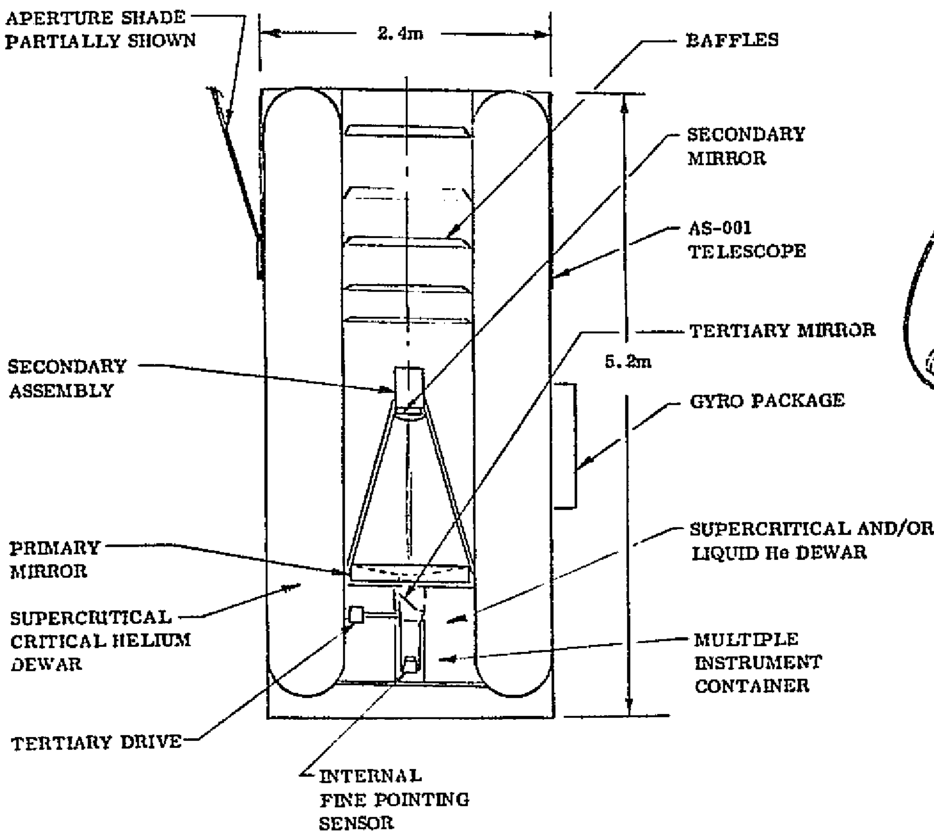
MISSION REQUIREMENTS

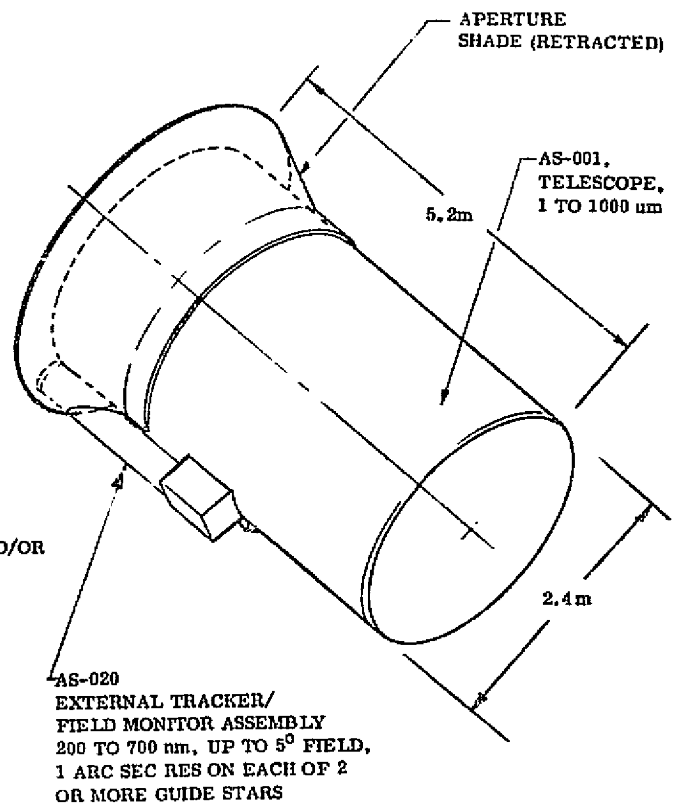
MEASURE LOCATION, FLUX DISTRIBUTION, BRIGHTNESS, & SPECTRUM OF VERY COOL IR SOURCES (MINIMUM IR INTERFERENCE FROM TELESCOPE)

⇨

TELESCOPE REQUIREMENT

SPECTRAL RANGE: 5 TO 1000 μm
COLLECTOR AREA: 1.8 m^2
OPERATING TEMP.: 20 TO 27 ($\pm$1)K
BACKGROUND $\leq 10^{-16}$ W $Hz^{-1/2}$
MIRROR FIGURE ERROR $< \lambda/20$ AT 5 μm





NOTE: Minimize internal heat sources and outside heat load leakage to enable maximum desired signal to IR local flux ratio and reduced helium usage.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.5

1. TECHNOLOGY REQUIREMENT (TITLE): Infrared Telescopes; Sensitivity improvement; minimization of local flux PAGE 7 OF 7

TECHNOLOGY NEEDS – REPRESENTATIVE CRYO COOLED 1.5m IR TELESCOPE

CATEGORY	REQUIRED CAPABILITY	STATE OF ART
SPECTRAL RANGE (μm)	5 TO 1,000	1 TO 500
LOCAL IR FLUX (INTERFERENCE) ($WHz^{-1/2}$)	$< 10^{-16}$	$\sim 5 \times 10^{-14}$
TELESCOPE INTERNAL TEMP (K)	20	4.2 to 77
EFFECTIVE COLLECTOR AREA (m^2)	1.8	0.64
MIRROR COLD FIGURE ERROR AT 5μm	$< \lambda/20$	$< \lambda/20$
MINIMUM DEWAR HOLD TIME (DAYS)	> 7 EXTENSION TO 30 & 90	0.5
MAX INTERNAL POWER DISSIPATION (W)	1	1 to 500
INTERNAL ATMOSPHERE	VACUUM, OR GHe	Vacuum, Air or GN_2
INTERNAL CLEANLINESS LEVEL	100	200 to 10,000

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.6

1. TECHNOLOGY REQUIREMENT (TITLE): LHE Cooled Telescope PAGE 1 OF 3

Extend design lifetime of liquid helium cooled experiment telescopes and sensors.

2. TECHNOLOGY CATEGORY: Cryogenic Control -Collectors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Extend the design life of a LHe cooled telescope to 12 months. Minimize local flux to enable cosmic background measurements The spatial and spectral distribution of the cosmic microwave background needs to be measured in the 100 μm to 3,000 μm range which is inaccessible from the ground.

4. CURRENT STATE OF ART: Current maximum lifetime of a LHe closed system is 90 days.

HAS BEEN CARRIED TO LEVEL 6

5. DESCRIPTION OF TECHNOLOGY

An IR telescope for wavelengths from 100 to 3000 micrometers with an aperture of 0.2m, FOV of 5 degrees, and f/15 optical system needs to be cooled to liquid helium temperatures to obtain maximum radiometric sensitivity and accuracy.

Some controversy exists as to what wavelengths will be most effective in determining the spatial and spectral distribution of the cosmic IR and microwave radiation field. The portion of the measurements in the 100 to 3,000 μm which tend to be inaccessible can best be accomplished from space by a cryogenically cooled IR telescope instrument.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. The whole telescope will be cooled to below 4.2°K to achieve the performance required to survey the spatial and spectral distribution of the cosmic microwave background radiation field.
b. The benefitting payload is AS-03-A, Cosmic Background Explorer.
c. The technology to extend the design life to one year will enable complete coverage of the sky with one satellite to map cosmic background radiation in the 100 to 3,000 μm range.
d. The Cosmic Background Explorer is desired to be launched in 1979, hence the proof of the experimental model can be combined with the initial observation flight. The basic initial technology demonstration would be performed in a good cooled vacuum chamber.

TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.6

1. TECHNOLOGY REQUIREMENT(TITLE): LHE Cooled Telescope PAGE 2 OF 3

Extend design lifetime of liquidhelium cooled experiment

7. TECHNOLOGY OPTIONS:

Trade studies required are:

a. Optimum operating temperature
b. Type of insulation and Dewar
c. Type of active cooling
d. Type of thermal control coatings
e. Light weight and small size to fit Explorer class vehicles

8. TECHNICAL PROBLEMS:

a. Need better insulating techniques
b. Realistic demonstration of selected solutions
c. Reliability of electrical and mechanical components.
d. Dewar for containing helium for one year (however, techniques being developed by Garrett Airesearch for the magnetic spectrometer are applicable on a smaller scale).

9. POTENTIAL ALTERNATIVES:

a. Launch a series of satellites with lesser design lifetimes.
b. Reduce sensitivity requirements to allow an increase in operating temperature.
c. Obtain cosmic background radiation measurements at other wavelengths.
d. Increase satellite size.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. W74-70256 (502-21-27), Space Vehicle Thermal Control, Goddard Space Flight Center, Stanford Ollendorf, (301) 982-5228.
b. W74-70257 (502-21-27), Thermal Control, Ames Research Center, John V. Foster, (415) 965-5083.
c. W74-70567 (180-31-51), Thermal Systems Management, Lewis Research Center, C. A. Aukerman, (216) 433-6223.
d. W74-70657 (188-78-51), Advanced Technological Development, General: Cryogenics, NASA, Washington, D. C., M. J. Aucremanne, (202) 755-3676.

EXPECTED UNPERTURBED LEVEL 6

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Solar electric powered helium recycling (RI-12.2)

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-1.6

1. TECHNOLOGY REQUIREMENT (TITLE): LHE Cooled Telescope PAGE 3 OF 3

Extend design lifetime of liquid helium cooled experiment

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY (Exp. Equip.)																			
1. Trades & Constraints Anl																			
2. Prelim. Design & Fabr.																			
3. Test and Evaluation																			
APPLICATIONS (Spacecraft)																			
1. Design (Phase C)																			
2. Development/Fabrication (Phase D)																			
3. Operations				T1															

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE		T																
NUMBER OF LAUNCHES					T1		T1		T1		T1		T1		T1		T1	7

14 REFERENCES:

a. Summarized NASA Payload Descriptions, Automated Payloads, July 1974, NASA/MSFC, p. 26.

b. Final Report of the Space Shuttle Payload Planning Working Group, Astronomy, May 1973, Goddard Space Flight Center, pp. 22-23.

Legend:

T - Technology

T1 = AS-03-A, Cosmic Background Explorer

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.7

1. TECHNOLOGY REQUIREMENT (TITLE): IR Scanner/Radiometer PAGE 1 OF 4
Improve accuracy of measurement of ocean surface temperature

2. TECHNOLOGY CATEGORY: Collectors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Measure sea surface temperature with an accuracy of 0.13°K over temperature range of 273 to 309°K. Improve instantaneous FOV to at least 0.7 milliradian (0.04 deg) and preferably to 0.21 mr (0.012 deg).

4. CURRENT STATE OF ART: Global maps of the ocean have been obtained to an accuracy of 1°K by Weather Service Satellite System, DMSP, FOV = 1°

HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY

The IR scanner radiometer is expected to sweep a 0.7 milliradian (0.04 degree) instantaneous field of view across a path ±40° from a perpendicular to the flight path, by means of a rotating or oscillating mirror. To obtain a good measure of ocean surface temperature versus spatial location (0.4 km), selected wavelengths in the 8 to 13 μm spectral region (probably 11.9 to 12.9 μm and 10.2 to 11.2 μm) will be used. The scanning mirror will collect sufficient energy from each 0.4 x 0.4 km^2 spatial resolution element on the ocean surface to produce a signal larger than the local IR flux. The scanner will review a calibration source at least one time per scan to enable attainment of observational accuracy desired. High resolution (0.4 x 0.4 km^2) is only required near the coastline.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Since a fairly wide ±40° scan, perpendicular to orbital direction and the instantaneous field of view of 0.04° are sized, dwell time on each element is not long. Consequently a fairly large collector is required (0.3 to 0.4 m aperture).

b. The current temperature accuracy per spatial element for IR scanner/radiometers is about 1° from space; the Seasat A goal is between 0.15 and 1°K. OP-07-A, Seasat B goal is 0.13°K.

c. Sensitive sea current and upwelling measurements depend upon detectivity of minute temperature gradients. The higher sensitivity and improved signal to noise ratio will permit refinements and additions to present ocean dynamics measurements. Areas to be surveyed are too great for periodic measurements from aircraft.

d. A very high resolution radiometer Type VHRR using 0.6, 0.7, 10.5, 12.5 μm has achieved 1°K measurements. The 0.13°K measurement capability from an orbital altitude of 600 km can be proved only by comparison against local measurements made from aircraft.

TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.7

1. TECHNOLOGY REQUIREMENT(TITLE): IR Scanner/Radiometer PAGE 2 OF 4

Improve accuracy of measurement of ocean surface temperature

7. TECHNOLOGY OPTIONS:

The design of a scanner/radiometer is constrained by the tradeoff between temperature sensitivity and spatial resolution. To obtain very fine resolution, a small ratio of detector size, d, and focal length, f, is required (hence a large focal ratio). As noted before, if f is large, the instantaneous field of view is very small, the radiant area viewed is smaller but a larger collector mirror is needed. The size of detector is expected to be in the order of 1 mm. The detector sensitivity is improved by cooling cryogenically.

Pushbroom arrays up to 5000 detectors per spectral band are being considered according to J. Pitts, Westinghouse Electric Corporation.

8. TECHNICAL PROBLEMS:

a. Collector size versus dwell time per spatial element.
b. The major technical problem is the effect of clouds and of the atmosphere between the satellite and the ocean surface. Although a systematic calibration chart versus angle from the local vertical can be developed by actual test comparisons of orbital readings against a local airborne radiometer, there is considerable variation in atmospheric masses giving some measure of uncertainty.
c. Correlation between sea state effects and water temperature.

9. POTENTIAL ALTERNATIVES:

A number of coordinated scanner/radiometer instruments operating simultaneously in a number of the IR and RF atmospheric windows may produce synchronized sets of data versus the same spatial elements, giving a better incremental and absolute radiometer accuracy. The multisensor multispectral alternative using RF bands as well as IR sensor channels may provide a correlated set of data enabling correction to 0.1°K. However, addition of microwave radiometer antennas, receivers, and data handling equipment, have greater weight, volume, and cost demands.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

W 74-70538 (177-55-11) Remote Sensing of Coastal Upwelling, Glen Goodwin, (415) 965-5065. (Indicates that NOAA II, FAMOS, ERTS-B, NIMBUS G thermal imagery now being used.)

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Development of a stable local calibration reference.
b. Development of correction charts of atmospheric IR measurements versus angle from local vertical.
c. Correlation between sea surface temperature and water temperature 0.3 m from surface.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.7

1. TECHNOLOGY REQUIREMENT (TITLE): IR Scanner/Radiometer PAGE 3 OF 4

Improve accuracy of measurement of ocean surface temperature

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Trades & Predesign	—																		
2. Exp Model Fabr.		—																	
3. Tests, Calibration & Evaluation			—																
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)				—	—														
2. Devl/Fab (Ph. D)						—	—												
3. Operations							T1	—	—	—	—	—	—						
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE			T															
NUMBER OF LAUNCHES								1										1

14. REFERENCES:

a. Summarized NASA Payload Descriptions, Level A Data, NASA PD, July 1974.

b. Preliminary Payload Descriptions, Vol. I, Automated Payloads, July 1974, pages 6-110 thru 6-126.

c. E & OP Applications Program, Vol. II, Rationale and Program Plans, September 1972

d. W 74-70538 (177-55-11). Remote Sensing of Coastal Upswelling.

(References continued on page 4.)

Legend

T = Technology

T1 = OP-02-A, Seasat B

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.7

1. TECHNOLOGY REQUIREMENT (TITLE): IR Scanner/Radiometer PAGE 4 OF 4

Improve accuracy of measurement of ocean surface temperature

14. REFERENCES: (Cont'd)

e. Definition of the Technical Requirements for an Earth Resources Payload, Vol. 5, Appendix A, Sensor Data, Table 3, Earth Resources Market Analysis of October 15, 1973.

f. Infrared-Optical Techniques Applied to Oceanography. Measurement of Total Heat Flow from the Sea Surfaces, E. D. McAlister, May 1964, Applied Optics.

g. A Radiometric System for Airborne Measurement of the Total Heat Flow from the Sea, E. D. McAlister and W. McLeish, Page 2697, Dec. 1970, Applied Optics.

h. Oceanography from Space, April 1965, Ref. 65-10 Woods Hole, E. D. McAlister and W. L. McLeish "Oceanographic Measurements With Airborne IR Equipment and Their Limitations, page 189.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.8

1. TECHNOLOGY REQUIREMENT (TITLE): VIS-IR Optics Experimental Techniques for Lasers;Communication Fineness and Stability of Alignment; Enable manual access as well as automatic and manual adjustment. PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Collectors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Alignment of multiple mirrors of optical system is desired within 0.04 arc second (may be mitigated for optical bench by choice of mirrors) to minimize wavefront distortion, avoid spoiling coherence, and enable tracking. Tracking of gimballed laser telescope will be good to about 1 arc second after initial acquisition search.

4. CURRENT STATE OF ART: Optically flat mirrors (even half silvered for beam splitting) and two axis mirror mounts manually adjustable up to 0.1 arc sec exist; however, neither adjustments for long optical trains nor the breadboard philosophy for laser experimentation have been proven yet. HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Modulated laser beams at 10.6, 1.06, 0.53 μm are used as carriers in a laser communication system. For experimenters to have access to the lasers and receiving circuitry, systems of mirrors are used to route received and transmitted beams to an optical telescope that is used for projecting and receiving the signals. To avoid damage to mirrors the outgoing laser beams are expanded to distribute laser energy over a greater reflection area. All the optics are to be mounted in a stable structure. Some of the mirrors are fixed but manually adjustable; some are on two axis mounts driven by error signals via analog or digital computing circuits to compensate for Space Lab or orbital vehicle motions as well as tracking errors. In practice, small optical mirrors cannot maintain beam coherence equivalent to 0.04 arc sec (Airy disc size is about 1 arc sec at wavelengths shown). However, as has been demonstrated by many autocollimators, angular detection devices track either the centroid or preferably the edges of a reflected image of a small mirror which may be blurred by diffraction and aberrations with an accuracy of 0.04 to 0.06 arc seconds. "Cat's Eye" type reflectors need to be researched to minimize need for sub-arcsecond alignment.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Although most of the optical system components for receiving and transmitting the laser communication to and from a Space Shuttle Orbiter payload are available, logic programming and servo system techniques need to be developed to enable integration of components.

b. The techniques are needed to implement CN-05-S, Laser Communication Experiment (MSFC version). An additional laser experiment proposed by GSFC with a new CN-XX-S number can be mounted outside the Spacelab cabin on the pallet. It is not accessible for manual experimentation during flight. However, the optical beam alignment and transfer techniques may be applicable to all payloads involving optical referencing, tracking, or pointing, where very good correlation and alignment are needed.

c. The techniques will enable development of techniques for proper detection and translation of laser signals from ground to space and space to ground. A later GSFC experiment will apply lessons learned toward development and test of practical laser communications equipment.

d. The technology requirement is satisfied when a similar optical system functions successfully in space. TO BE CARRIED TO LEVEL 7

1. TECHNOLOGY REQUIREMENT(TITLE): VIS-IR Optics Experimental Techniques for Lasers;Communications Fineness and Stability of Alignment; enable manual access as well as automatic and manual adjustment.

7. TECHNOLOGY OPTIONS:

A preliminary review of the current state of the art indicates that the uplink and downlink optical transmission trains can be corrected by servoed beam deflectors driven by error signals obtained from tracking detectors. However, no existing system for as many optical elements exist. The most critical beam deflectors are those coupling the gimballed telescope to the internal laser and detector optics. Tracking capability will depend largely on the accuracy and stability of the optics train used to track the incoming laser signals. Use of a stable optical base and strategic layout of optical trains will reduce the number of servoed deflectors to a minimum.

A major trade exists as to whether a multiple carrier laser communication experiment in breadboard (optical bench) form or the finished operational form is flown.

Plane parallel plates in divergent or convergent optical space can provide up to 100:1 advantage in beam angular adjustments.

8. TECHNICAL PROBLEMS:

a. Optical path extends from pallet in shuttle orbiter to pressurized module and is subject to large deflections and distortions.

b. Use of a number of movable mirrors in passing the beam through a multiaxis mount as well as the beam deflectors requires a systematic allocation of corrections in each axis of each deflector.

c. Tracking pointing needs to be accomplished to within a fraction of a beamwidth (0.1 arc sec for 1 arc sec beam) simultaneously with alignment of laser signal optical trains; interactions may occur.

9. POTENTIAL ALTERNATIVES:

a. A computer controlled alignment system using auxiliary corner reflectors or fiducial marks on each servoed mirror might enable balanced correction of errors in alignment of mirrors.

b. A more reliable laser communicator unit mounted on standard gimbals (Instrument Pointing System) can be used in later communications experiments. It avoids laser beam tracking through windows and on optical bench but is not accessible for human manipulation.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. W74-70344 (502-03-11) Optical Communication Research, GSFC, H. H. Plotkin, (301) 982-6171.

b. Communication Exp. Definition, TRW Report DR-MA-04, pages 9-1 thru 9-19, Appendix A, 9A-1 thru 9A-15 under study from MSFC (C. Quantock).

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Telescope pointing to 0.1 seconds (beam adjustments to sub-arcseconds can be accomplished by use of plane parallel plates in divergent or convergent optical space to obtain a lever effect where the actual mirror angle can be adjusted only with a precision of several arc seconds).

b. Tracker and alignment detector errors less than 0.1 arc seconds to minimize accumulative errors of several loops.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-1.8

1. TECHNOLOGY REQUIREMENT (TITLE): VIS-IR Optics Experimental Techniques for Lasers;Communication Fineness and Stability of Alignment; enable manual access as well as automatic and manual adjustment. PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Parametric Analysis	—	—																	
2. Comm. Breadboard			—	—															
3. Test & Evaluation				—	—														
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)					—	—													
2. Devl/Fab (Ph. D)						—	—												
3. Operations								●	●	●			●	●	●				
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					T													
NUMBER OF LAUNCHES								1	1	1			1	1	1			6

14. REFERENCES:

a. Definition of Experiments and Instruments for a Communication/Navigation Research Laboratory, Vol. II, Experiment Selection, Study Report DR-MA-04, May 1972, TRW, pages 9-1 thru 9-19, Appendix A pages 9A-1 thru 9A-15.

b. Summarized NASA Payload Descriptions, Sortie Payloads, Level A Data, NASA PD, July 1974.

c. Preliminary Payload Descriptions, Volume II, Sortie Payloads, Level B Data, NASA, July 1974.

d. Ltr. from Robert T. Martin of Barnes Engineering Company to H. Ikerd, 27 Dec. 1975.

Legend

T = Technology

● = Sortie Operations

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-1.9

1. TECHNOLOGY REQUIREMENT (TITLE): LARGE MICROWAVE ANTENNA ARRAYS PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Collectors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Maintain the required dimensional accuracy of large foldable antenna arrays in terms of flatness and phase-feed point dimensions.

4. CURRENT STATE OF ART: Antenna structure can be designed and manufactured to the required tolerances, but maintenance of the tolerances in the extreme thermal conditions of space is not in the S.A. HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

The subject advancement is representative of structural requirements for large (over 5m) foldable microwave antenna arrays for active and passive earth sensing applications. Flatness requirements range from 1/4 to 1/20 wavelength. For instance, the ATL printed circuit array antenna which will support simultaneous measurements in altimetry, scatterometry and passive radiometry will require surface flatness during operation less than 0.25 CM. During the Shuttle era, antenna lengths up to 30 meters long (Met. Radar Facility) are planned. They will be articulated or deployable, and will receive varying thermal flux contributions from the earth's albedo, the sun, and the Shuttle/Spacelab assembly.

Foldable antenna arrays, up to 30 m. long have not been built to date. A 14 meter long printed phase array is being designed for SEASAT. Although flatness tolerances of 0.25 CM over a 25 meter span are well within current manufacturing capabilities, the maintenance of these tolerance limits under the expected space thermal conditions is not within the state of the art.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) The required dimensional tolerance of antenna arrays will be based on operating frequencies ranging up to 100 GHz and the criteria of 1/4 to 1/20 wavelength contour accuracy. The optimum frequency upon which the design will be based will consider the required altitude and radiometric measurement accuracy and degree of weather penetration.

(b) This technology advancement specifically supports: the Slotted Waveguide Antenna for Payload No. ST- 22S (ATL); the Shuttle Imaging Microwave System, EO-05S; Multifrequency Radar Land Imagery, OP-02S; Multifrequency Dual Polarized Microwave Radiometry, OP-03S; and the Millimeter Wave Experiment.

(c) This advancement will be instrumental in attaining altitude measurements with less than one meter error for averaging times of ten seconds, land and ocean imaging, microwave soundings of the atmosphere and other earth observation applications.

(d) Structural models of the antenna array should be tested in simulated thermal vacuum conditions.

TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-1.9

1. TECHNOLOGY REQUIREMENT(TITLE): LARGE MICROWAVE ANTENNA ARRAYS

7. TECHNOLOGY OPTIONS:

The 1/4 to 1/20 wavelength flatness criterion will be relaxed, in some instances, depending on the allowable degree of measurement degradation. The antenna dimensional tolerance will significantly affect microwave beamwidth, sidelobes, and system efficiency. Methods of actively adjusting the position of individual antenna segments to compensate for deflecting influences such as thermal gradients or inertial loads are theoretically possible, but may introduce undue complexity and program cost.

8. TECHNICAL PROBLEMS:

Thermally induced deflections must be minimized through proper material selection and structure design. The hinge mechanism must be properly indexed to permit proper parallelism between antenna segments and its elements after antenna deployment (unfolding). Special test procedures must be developed to simulate zero-g for pattern measurements and thermal distortion measurements. Erectable antenna structures 10 to 30 meters long, built for maximum weight saving, will be subject to serious distortion forces due to gravity during ground testing.

9. POTENTIAL ALTERNATIVES:

Altimetry measurements will be feasible through use of a smaller array or parabolic antenna, as indicated in DTR No. GE-4.4. However, the high resolution microwave radiometry and imaging applications will require a large array.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a) RTOP W74-70492 Earth Observations Radar Workshop
b) RTOP W74-70274 Structural-Thermal - Optical Program
c) Additional technology program emphasis will be required to insure availability of the required antenna technology early in the Shuttle Program.

EXPECTED UNPERTURBED LEVEL 3

11. RELATED TECHNOLOGY REQUIREMENTS:

The development of the subject antenna technology must be done in conjunction with the analysis and advancements in microwave systems for altimetry, scatterometry, radar imaging, and passive microwave radiometry. The advances in holographic microwave techniques will be relevant to the subject requirement, since the dimensional tolerances on the antennas will be more stringent.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-1.9

1. TECHNOLOGY REQUIREMENT (TITLE): LARGE MICROWAVE ANTENNA ARRAYS PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Thermal/Structural Anal.	—																		
2. Material Selection		—																	
3. Range Tests of Prototype.			—																
4. Space Qualification				—															
APPLICATION																			
1. Design (Ph. C)					—														
2. Devl/Fab (Ph. D)					—														
3. Operations						—	—	—	—	—	—	—	—	—	—	—	—		
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					Δ													
NUMBER OF LAUNCHES						5	5	4	4	4	3	4	5	4	6	5	4	53

14. REFERENCES:

1. Study of Shuttle Compatible Advanced Technology Laboratory ATL. TM-X-2813

2. Shuttle Imaging Microwave System (SIMS), Perspectives and Objectives, by Dr. J. Waters, JPL, January 22, 1974.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.1

1. TECHNOLOGY REQUIREMENT (TITLE): Spatial Detector; PAGE 1 OF 4
Spatial readout resolution, dimensional stability, (cosmic or gamma rays)

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Measure gamma ray or nuclear particle's trajectory through spatial detector to 0.1mm (and preferably to 0.01mm) with relative position to 0.002mm over 1.2m range to enable detectible rigidity from 200 GV/c to 10^4 GV/c.

4. CURRENT STATE OF ART: Current state of art provides a spatial resolution of ± 0.2mm with four measurements averaged to provide ± 0.1mm per detector element which is equivalent to a maximum rigidity of 200 GV/c. HAS BEEN CARRIED TO LEVEL 6

5. DESCRIPTION OF TECHNOLOGY

Spatial detectors can sample a gamma ray or nuclear particle trajectory at 3 or 4 points. Each point should be measured at least to ± 0.1mm. The current positional accuracy capability combined with the field from a superconducting magnet for a cosmic ray will yield a spectrometer mean maximum detectible rigidity of 200 GV/c with $\pm$ 0.1 mm measurements and in the future to 10^4 GV/c with 0.002mm measurements. Conventionally, each spatial detector would consist of a multiwire proportional chamber with delay line readout. The charge deposited by a cosmic ray is drawn to the closest wire in the chamber and multiplied in the detector gas. The time required for the induced signal to propogate to the end of the delay line attached to the wire indicates the location where ionization occurs. The resultant value is digitized for output. Time of flight measurments enables identification of tracks as gamma ray or as cosmic rays, and provide an additional measure of energy through determination of velocity.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D.

6. RATIONALE AND ANALYSIS:

a. When traversing a magnetic field, a charged particle is bent through an angle which is proportional to its rigidity (momentum/unit charge). Hence a higher energy particle's trajectory is bent less, requiring more precise readouts. Gamma rays, of course, are not bent, but can be converted to $e^+ e^-$ pair, which is bent.

b. Payloads benefiting from improvement in spatial detector resolution and accuracy include HE-15-S and HE-09-A, 'Magnetic Spectrometer". Spatial detector techniques are also applicable to HE-08-A, Large High Energy Observatory (Gamma Ray).

c. Improvement in spatial detector resolution and stability of 10 to 50 times the accuracy of present day gaseous or proportional spark chambers would extend the useful range of magnetic spectrometers as high as 10^4 GV/c. Greater accuracy in determining direction of arrival of gamma rays is needed.

d. Improved spatial detectors can be tested by installation in early or existing magnetic spectrometers used in balloon flights as well as in gamma ray instruments. These early tests should indicate feasibility by 1976.

TO BE CARRIED TO LEVEL 8

1. TECHNOLOGY REQUIREMENT(TITLE): Spatial Detector;
Spatial readout resolution, dimensional stability, (cosmic or gamma rays)

7. TECHNOLOGY OPTIONS:

Conventional measurements of gamma ray or particle trajectories (in a magnetic field) utilize proportional and spark chamber technology. Solid state high spatial resolution detectors not using gas as a detection medium are being investigated using stable substrates.

Considerable improvement can be obtained by measuring positions of spatial detectors relative to each other by auxiliary optical systems. Calibrations better than 0.01 mm by straight trajectories will help. With the magnetic field applied, the bend angle for various energy particle may be determined by measurements at four locations. Four measurements of the particle's path allow greater rejection of background than would three.

8. TECHNICAL PROBLEMS:

a. For gaseous proportional or spark chambers, the temperature should remain within $\pm 5^{\circ}$ C and the pressure within 0.05 atmosphere of the desired limits. Other than data readout variations and triggering, there appear to be few problems in attaining performance of $\pm$0.1mm accuracy. Higher accuracy appears to require non-gaseous proportional chambers.

b. Selection of high structural stability and low outgassing materials.

c. There is a problem in delay line readout of multiwire proportional counters due to two particles (e^+ and e^-) transversing the counters. There appears to be no solution in sight for the delta rays associated with extending performance to charge 26.

9. POTENTIAL ALTERNATIVES:

A spatial detector system consisting of four plates of detector per spatial detector axis. Instead of using conventional proportional or spark chamber technology which usually means arrays of wires and gas, each plate would consist of a thin array of detectors which measure location and time of flight of a gamma ray or nucleon thru the plates. In addition, the detector elements provide coincidence-anticoincidence triggers to define the FOV geometry, charge magnitude, time of flight of each particle or gamma ray. (Some instruments require identification of track as a cosmic ray or gamma ray type.)

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. RTOP W74-70646 (188-46-56) Particle Astrophysics, NASA HQ, Albert G. Opp, (202) 755-3665.
b. RTOP W74-70651 (188-46-64), Astrophysical Investigations on the Space Shuttle, NASA HQ, Albert G. Opp, (202) 755-3665.
c. RTOP W74-70652 (188-46-64), Shuttle Definition Studies for High Energy Astrophysics, F. B. McDonald, GSFC, (301) 982-4801.

EXPECTED UNPERTURBED LEVEL 6

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Magnetic field uniformity and predictability (DeWar/Cryostat/Magnet Assembly).
b. Uniformity and knowledge of spatial detector temperature.
c. Automatic cryostat/Magnet control.
d. Spatial detector electronics (subnanosecond circuitry).
e. Pressurizable thermal control shield with minimum loss & secondary radiation.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-2.1

1. TECHNOLOGY REQUIREMENT (TITLE): Spatial Detector; Spatial readout resolution, dimensional stability, (cosmic or gamma rays) PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Options & Para. Anal.																			
2. Design of Exp. Model																			
3. Fabrication & Assembly																			
4. Tests & Evaluation																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations						● M1		M2	● M1					● M1					
4.							● G1		● G1				● G1				G2		

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		TOTAL
TECHNOLOGY NEED DATE		M1 M2																	
NUMBER OF LAUNCHES						M1 M2	G1		M1 G1			G2	G1	M1					8

14. REFERENCES:

a. Final Report of the Space Shuttle Payload Planning Working Groups, Vol. 3, High Energy Astrophysics, May 1973, pages 39 and A-23.

b. Superconducting Magnetic Spectrometer Experiment for HEAO Mission B, Part I Preliminary Design and Performance Specifications, Contract NAS 8-27408, 1 June 1971 thru 15 Feb. 1972, Control No. DCN 1-1-21-00090(IF).

(Continued on Page 4)

Legend

M1 = Sortie Flight of Magnetic Spectrometer (HE-15-S)
M2 = Automated Flight of Magnetic Spectrometer (HE-09-A)
G1 = Prototype Gamma Ray Sortie Mission Instrument (HE-16-S)
G2 = Automated Free Flyer Gamma Ray Instrument (HE-08-A)
● = Sortie Operations
— = Automated Operations

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

*Also G1 and G2.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.1

1. TECHNOLOGY REQUIREMENT (TITLE): Spatial Detector; PAGE 4 OF 4
Spatial readout resolution, dimensional stability, (cosmic or gamma rays)

14. REFERENCES: (Cont'd)

c. Introduction of Experimental Techniques of High Energy Astrophysics, H. Ogelman and J. R. Wayland, GSFC, 1970.
d. Summarized NASA Payload Descriptions, Level A Data, Automated Payloads, NASA PD, July 1974.
e. Preliminary Payload Descritions, Vol. I, Automated Payloads, Level B Data, July 1974.
f. Summarized Level A and Level B Descriptions, Vol. II, for Sortie Payloads, July 1974.
g. High Resolution Readout of Multiwire Proportional Counters Using the Cathode Coupled Delay Line Technique, by J. L. Lacy and R. S. Lindsey, JSC, March, 1973.
h. A Direct Measurement of Magnetic Rigidity Spectra of Cosmic Ray, J. H. Adams, North Carolina State University at Raleigh, N.C., JSC Doc. MTM-TN2-71, January 1973.
i. Superconducting Magnetic Spectrometer for Cosmic Ray Nuclei, Review of Scientific Instruments 43, 1, January 1972.
j. A Measurement of Cosmic-Ray Rigidity Spectra Above 5 GV/c of Elements from Hydrogen to Iron, Astrophysical Journal 180, 987, March 1973.
k. Spatial Spark Jitter Measurements of Highly Charged Nuclei for Optical Spark Chambers, Review of Scientific Instruments, 43, 1285, September 1972.
l. "Superconducting Magnet and Cryostat for a Space Application", and "Low Heat Leak Current Leads for Intermittent Use", G. F. Smoot and W. L. Pope, to appear in Vol. 20, Advances in Cryogenic Engineering (1974).

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C- 2.2

1. TECHNOLOGY REQUIREMENT (TITLE): X-Ray Transmission Grating PAGE 1 of 4
Dimensional stability of elements versus temperature, g level, size

2. TECHNOLOGY CATEGORY: Sensor

3. OBJECTIVE/ADVANCEMENT REQUIRED: Spectral resolving power of $\lambda/\Delta\lambda$ - 5 & 200 at 0.31 to 12.4 nm respectively, for signal input of 3×10^{-3} photons/sec cm^2 arc $minute^2$; survive launch acceleration to 5 g; $263^{o}K$ to $303^{o}K$; grating dia. = 0.5m.

4. CURRENT STATE OF ART: A 0.3m dia. transmission grating of 1400 lines per mm with gold evaporated on it at a near-grazing angle was used on the Skylab ATM in the 0.3 to 6 nm range.

HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY

Low resolution spectral data are obtained by dispersing incident X-rays from an X-ray telescope with a transmission grating located near the telescope mirror. Each point source in the field of view results in a point image and a line image in which the position along the line follows the normal grating function of the wavelength. The spectral resolution is poorer than obtained with crystal spectrometers but since data are taken simultaneously over the entire spectral range, a higher data rate is obtained which enables investigation of weaker sources and of temporal behavior of stronger sources.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Dimensional stability of the transmission grating lines to avoid permanent distortion by ascent and versus temperature change are critical as well as materials used for stabilizing the grating. Progressive improvement and tests will result in rugged transmission gratings for each type of x-ray telescope.

b. The transmission grating is useful in the 1.2m X-ray (HE-11A) telescope as well as the Large X-ray telescope (HE-01-A). It could also be applied in 4 more types of telescopes.

c. An improved transmission grating capable of handling X-rays from 0.1 keV to 4 keV (0.31 to 12.4 nm) properly coupled to the Large X-ray telescope and appropriate detector will enable low resolution spectroscopy at very faint signal levels.

d. Transmission gratings for X-ray telescope flown in 1973; larger greater range grating needs to be developed.

Test to be performed in cooled vacuum chamber to demonstrate technology.

TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.2

1. TECHNOLOGY REQUIREMENT(TITLE): X-Ray Transmission Grating PAGE 2 OF 4

Dimensional stability of elements versus temperature, g level, size

7. TECHNOLOGY OPTIONS:

The X-ray transmission grating intercepts an X-ray beam of 1° at a point 0.5m in diameter. It is used in conjunction with a maximum sensitivity detector or an X-ray converter/image intensifier for low resolution spectroscopy at very faint signal levels (flux $\sim 3 \times 10^{-3}$ X-ray photons per sec per cm^2 per arc $minute^2$).

8. TECHNICAL PROBLEMS:

Primary problem is dimensional stability of transmission grating line spacing during ascent and descent versus g level and temperature change. Grating mounting needs to be stable (with little residual vibration or movement during an observation); however should be stowable outside of X-ray beam when not wanted and should be axial adjustable by remote control.

9. POTENTIAL ALTERNATIVES:

a. Primary ruled reflection grating, platinum on glass, holographically ruled.

Such gratings, however, usually are designed for smaller angular divergence than produced by typical X-ray mirrors.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

EEOP: W 74-70631, X-ray Astronomy, N. G. Roman

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

X-ray telescope (development of better sensitivity, spatial resolution, and field of view).

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-2.2

1. TECHNOLOGY REQUIRFMENT (TITLE): X-Ray Transmission Grating PAGE 3 OF 4

Dimensional stability of elements versus temperature, g level, size

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Trades, Anal., Design	—																		
2. Sample Grating Fab.		T1	T2		T3														
3. Test & Evaluation			T1,	T2			T3												
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)					T1,	T2			T3										
2. Devl/Fab (Ph. D)							T1,	T2			T3								
3. Operations							T1—	—	—	—	—	—							
								T2—	—	—	—	—	—						
											T3—	—	—	—	—	—	—	—	—
4.										T4 ⊙	●	⊙		●		●	●		
							T5	●											

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					T1 T2			T3										
NUMBER OF LAUNCHES								T1 T5	T2	T5	T4	T3 T4		T4		T4	T2 T4	11

14. REFERENCES:

a. Final Report of the Space Shuttle Payload Planning Working Groups, NASA/GSFC, May 1973, pages A-1, -2, A-4.

b. Summarized NASA Payload Descriptions, Sortie Payloads, PD, NASA, July 1974, pages 112, 113, 114.

(References Continued on Page 4)

Legend

● = Sortie operations

— = Automated operations

(T1) = HE-03-A, 0.75m X-ray Telescope (82-A), (85, 86, 88, 90, 91-S).

(T2) = HE-11-A, 1.2m X-ray Telescope (82, 84-S), (83, 91-A).

(T3) = HE-01-A, Large X-ray Telescope Facility (1986).

(T4) = HE-19-S, Low Energy X-ray Telescope.

(T5) = HE-20-S, High Resolution X-ray Telescope.

A = Automated (free flyer) S = Sortie

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.2

1. TECHNOLOGY REQUIREMENT (TITLE): X-Ray Transmission Grating PAGE 4 OF 4

Dimensional stability of elements versus temperature, g level, size

14. REFERENCES: (Cont'd)

c. Payload descriptions, Vol. I, Automated Payloads, Level B Data, NASA, July 1974, HE-03-A, HE-11-A, HE-01-A; pages 2-31 thru 2-56, 2-131 thru 2-158, and 2-1 thru 2-28.

d. Conference, S. S. Holt with E. Saari, 6 November 1974, at GSFC.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.3-1

1. TECHNOLOGY REQUIREMENT (TITLE): X-ray Max. Sensitivity Detector PAGE 1 OF 5
Detector window passband efficiency, charged particle rejection

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Achieve sensitivity of 3×10^{-4} counts per cm^2-second-arc minute^2, spectral range 0.1 to 4 keV (0.31 to 12.4 nm), sectional detectors for anticoincidence

4. CURRENT STATE OF ART: The current state of the art very nearly meets technology goal except for closed cycle cooling system and a front window transparent to X-rays from 0.1 to 4 keV.

HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY

The detector concept includes a supercooled Si (Li) detector cooled to 70 to 120°K with a transparent front window. The primary detector is surrounded by anticoincidence solid state detectors to minimize background arising from charged particles and Compton scattered photons. The detector front window should be capable of passing 0.1 to 4 keV (12.4 to 0.31 nm) X-ray photons and rejecting the local flux of charged particles. The current state of the art very nearly meets the technology goals except for a closed cycle cooling system and a front window transparent to the desired spectral range.

The detector assembly for HEAO-B currently employs solid methane, with ammonia as a secondary refrigerant. The current detector cannot operate below 0.4 keV because of noise. The capacitance of the detector is a problem. Segmenting would help and could reduce the capacitance effect to a fraction of a picofarad. The quality of FET preamplifiers is currently going downward and needs improvement.

See pages 4 and 5 for additional technology description.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Solid state detectors, with cooling, have the best presently obtainable detector spectral response and efficiency using a direct photo electric interaction. When used with the Large X-ray Telescope, the detector will enable sources 10^{-8} SCO X-1 to be detected (detector will be capable of a sensitivity of 3×10^{-4} counts/cm^2-sec-arc minute^2 as limited by effectiveness of rejection of charged particles).

b. Any or all of the X-ray telescopes of HE-19-S, Low Energy X-Ray Telescope, HE-11-A, Large High Energy Observatory D, HE-01-A, Large X-Ray Telescope Facility Observatory, can use a maximum sensitivity detector to improve total system effectiveness.

c. A maximum sensitivity detector enables realization of full sensitivity of an X-ray telescope particularly at the lower energy levels. Improvement in segmenting will also provide mapping or imaging data.

d. When a maximum sensitivity detector can be operated with a large X-ray telescope and effectively rejects background from charged particles and Compton scattered photons, these technology requirements are satisfied. Test should be performed in a HEO-B spacecraft in 1978 on an Atlas/Centaur launch.

TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.3-1

1. TECHNOLOGY REQUIREMENT(TITLE): X-ray Max. Sensitivity Detector PAGE 2 OF 5

Detector window passband efficiency, charged particle rejection

7. TECHNOLOGY OPTIONS:

Trades of detector size, coincidence-anticoincidence configurations, entrance window material, cryogenic cooling are expected to produce a maximum sensitivity detector whose threshold sensitivity, limited by sky background, can detect 3×10^{-4} counts per cm^2-sec-arc $minute^2$. Due to the necessity for rejecting charged particles and Compton scattering components, considerable detector electronics are needed for coincidence-anticoincidence gates, pulse height (energy) analysis, and output registers to handle the considerable dynamic range in counting rate and energy range. Segmenting, besides improving spatial resolutions, will reduce noise and eventually enable operation down to 0.1 keV. Charged particle influx may be minimized by using a permanent magnet to sweep aside low energy protons or electrons. Gamma ray noise, except down the detector axis, will be minimized by anticoincidence circuits.

8. TECHNICAL PROBLEMS:

a. There is a problem of enclosing the active Si (Li) within the anticoincidence volume and yet providing adequate cold finger contact. Due to the small dimensions of the detector, time of flight values are small for X-rays. However, signal may be gated for durations up to use.
b. Conversely, increase of area increases the background count rate.
c. Mounting to minimize microphonics.
d. Need many detectors on the same silicon chip.
e. Front window transparency vs. anticoincidence effectiveness.
f. FET preamplifier noise.
g. Gama ray interference.

9. POTENTIAL ALTERNATIVES:

a. Since detector and anticoincidence dimensions tend to be too small for effective use, multiple layer detector arrays of larger size give more effective anticoincidence "shielding".
b. Image converter/intensifier of high sensitivities, low background noise level, and anticoincidence shielding. However, entrance window efficiency over total spectral range is a problem.
c. Scintillation Shield (such as CsI (Na) counter anticoincidence system).

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. RTOP, W74-70631 X-ray Astronomy, N. G. Roman.
b. HEAO B, 0.875m X-ray Telescope, R. Giaconni, ASE.
c. Additional X-ray telescopes gradually improve in collector area sensitivity, and angular sensitivity. (The telescope instrument definitions usually include options for maximum sensitivity detectors.)

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Large area X-ray telescope focusing X-ray to about 1 cm detector area.
b. Cryogenics for holding detector material at low noise levels for long durations.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C - 2.3-1

1. TECHNOLOGY REQUIREMENT (TITLE): X-ray Max Sensitivity Detector PAGE 3 OF 5

Detector window passband efficiency, charged particle rejection

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Trades, Tests, Analysis		T1, T2			T3														
2. Design & Fab. Imp. Prototype			T1, T2				T3												
3. Tests & Evaluation																			
APPLICATIONS					T1, T2				T3										
1. Design (Phase C)							T1, T2				T3						T1	(5)	
2. Development/Fabrication (Phase D)								T1		T2									
3. Operations							T2	T1					T3				T2		

13. USAGE SCHEDULE

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	Total
TECHNOLOGY NEED DATE					T 1 T 2			T3										
NUMBER OF LAUNCHES								T 1 T 2	T 2	T 2	T 1 T4	T 1 T 3 T4		T 1	T4	T 1 T4	T 1 T 2 T4	16

14. REFERENCES:

a. Final Report of the Space Shuttle Payload Planning Working Groups, NASA/GSFC, May 1973, pages A-1, -2, A-4.

b. Summarized NASA Payload Descriptions, Sortie Payloads, PD, NASA, July 1974, pages 112, 113, 114.

c. Payload Descriptions, Vol. I, Automated Payloads, Level B Data, NASA, July 1974, HE-03-A, HE-11-A, HE-01-A; pages 2-31 thru 2-56, 2-131 thru 2-158, and 2-1 thru 2-28.

d. Conference, S. S. Holt with E. Saari, 6 Nov. 1974, at GSFC.

e. Comments, M. Lampton, UCB, Berkeley, CA.

LEGEND

• Sortie operations

— Automated operations

(T 1)= HE-03-A, 0.75 m X-ray Telescope (82-A), (85, 86, 88, 90, 91 - S).

(T 2)= HE-11-A, 1.2 m X-ray Telescope (82, 84 - S), (83, 91 - A).

(T 3)= HE-01-A, Large X-ray Telescope Facility (1986).

(T4)= HE-19-S, 1.2m X-ray Telescope (Sortie Mission in 1985, 1986, 1990, 1991).

A = Automated (free flyer); S = Sortie

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

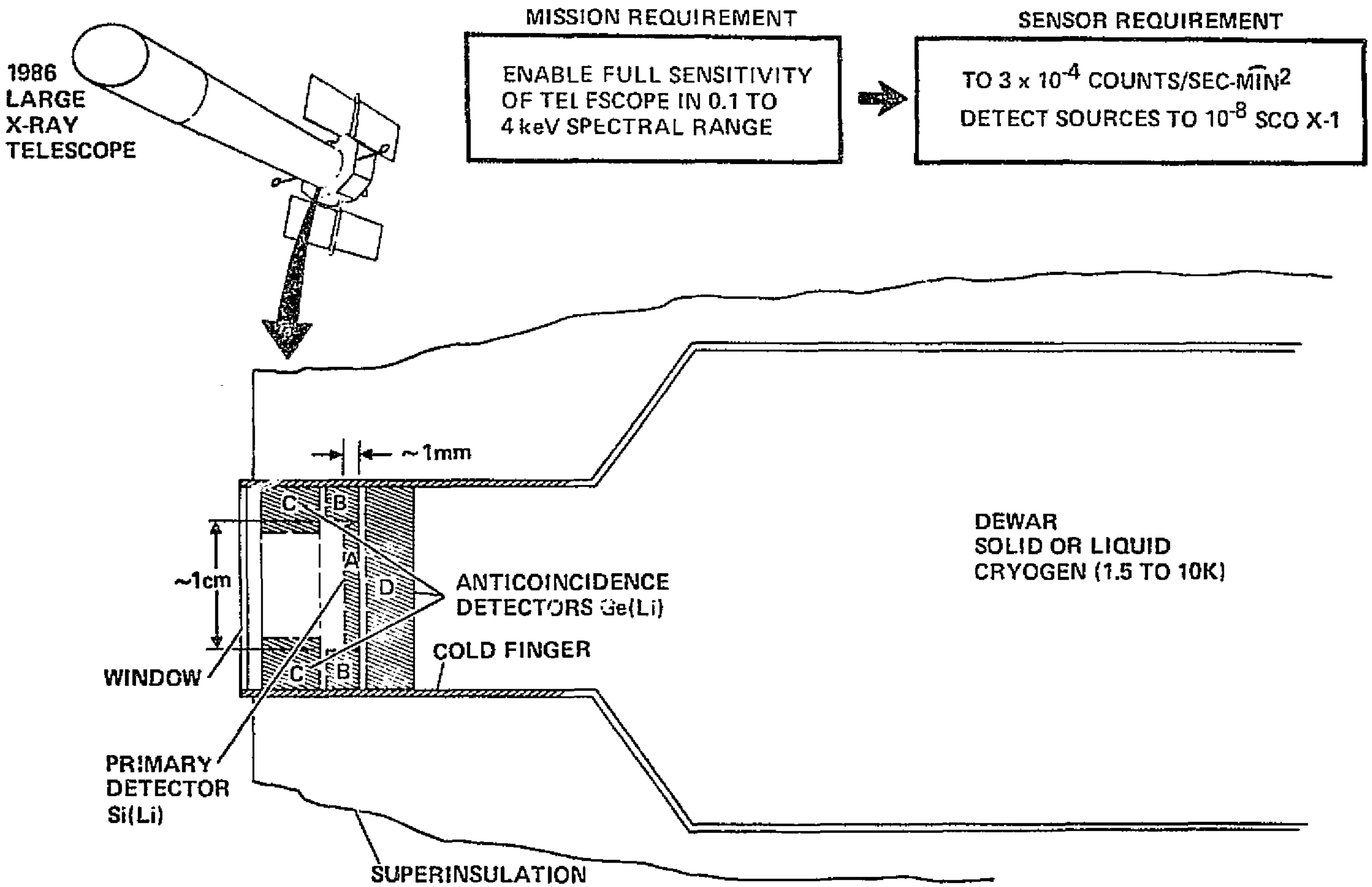
DEFINITION OF TECHNOLOGY REQUIREMENT

NO. C-2.3-1

1. TECHNOLOGY REQUIREMENT (TITLE) X-ray Max Sensitivity Detector PAGE 4 OF 5

Detector window passband efficiency, charged particle rejection

SENSOR REQUIREMENTS — X-RAY MAXIMUM SENSITIVITY DETECTOR



DETECTOR CONCEPT

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.3-1

1. TECHNOLOGY REQUIREMENT (TITLE): X-ray Max Sensitivity Detector PAGE 5 OF 5

Detector window passband efficiency, charged particle rejection

TECHNOLOGY NEEDS — MAXIMUM SENSITIVITY DETECTOR

ITEM	CAPABILITY REQUIRED	STATE OF ART
DETECTOR WINDOW PASS BAND (keV)	0.1 TO 4	0.1 TO 10
DETECTOR WINDOW PROTON/ELECTRON LIMIT, (COUNTS/SEC-MIN^2)	3×10^{-4}	1×10^{-3}
ANTICOINCIDENCE SHIELD SPURIOUS EVENT LIMIT (COUNTS/SEC-MIN^2)	10^{-4}	10^{-3}
TEMPERATURE CONTROL AT SELECTED TEMPERATURE IN RANGE 1.5 TO 10K	+0.5	+2
CLOSED CYCLE REFRIGERATOR ENDURANCE (YR)	2	0.25
DETECTOR SENSITIVITY (COUNTS FOR 1,000 SEC)	1	10

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. C-2.3-2

1. TECHNOLOGY REQUIREMENT (TITLE): X-ray Polarimeter Sensitivity; dimensional stability — PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Obtain polarization measurements up to 1% (at least 3%) accuracy at selected spectral lines in 0.1 to 4 keV spectral range (such as at 2.62 keV) with the polarimeter at focus of an X-ray telescope.

4. CURRENT STATE OF ART: Estimated state of art is 10% polarization measurements in 6 to 10 keV range with a flux of 2×10^{-3} photons cm^{-2} sec^{-1} keV^{-1}.

HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

Current concepts for an X-ray polarimeter at the focal point of an X-ray telescope indicate potential use of graphite, LiH, or similar materials in crystals for polarimeters. When soft X-rays are reflected through $\pi/2$ rad (90^{o}) of a crystal lattice, only the polarization component normal to the incident and reflected rays contributes effectively to the output signal. A proportional counter is in the direction of the polarized component output and polarization is detected by rotating the entire assembly around the telescope axis and measuring reflected power as a function of angle. A polarized X-ray source will output a maximum in the counting rate when the azimuthal angle is such that the plane of the incident X-ray crystal normal and reflected ray are perpendicular to the polarization of the incident ray.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Within an X-ray telescope field of view of 1°, 1 to 3% polarization measurement accuracy capability, compatible with large X-ray telescopes, is desired to enable identification and quantitative evaluation of synchrotron X-ray emission processes in the source examined.

b. Payloads benefitting from the polarimeter development include: HE-19-S, Low Energy X-ray Telescope; HE-20-S, High Energy X-ray Telescope; HE-11-A, Large High Observatory D (1.2m X-ray Telescope), and HE-01-A, Large X-ray Telescope Facility.

c. The technology advancement to 1% from current estimated 10% polarization measurement accuracy enables better estimates of X-ray source synchrotron emission process outputs.

d. When 1% polarimeters function in a space equivalent environment to the accuracy desired, this technology requirement is satisfied.

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TO BE CARRIED TO LEVEL 7

1. TECHNOLOGY REQUIREMENT(TITLE): X-ray Polarimeter PAGE 2 OF 3

Sensitivity; dimensional stability

7. TECHNOLOGY OPTIONS:

Energy bands for X-ray polarimeters are chosen to insure maximum likelihood of obtaining significant physical and cosmological insight into selected spectral lines corresponding to materials and processes found in the source. Most of the current options for X-ray polarimeters involve selected crystals in symmetric slab format. The prevailing concept is based upon the fact that X-rays can be reflected thru $\pi/2$ rad (90°) by a crystal slab with lattice planes oriented at $\pi/4$ rad (45°) to the telescope symmetry axis. The reflected ray contains only one polarization component which can be readout by a proportional counter array .

8. TECHNICAL PROBLEMS:

Secondary radiation around the X-ray telescope can give rise to polarization measurement errors.

9. POTENTIAL ALTERNATIVES:

A multichannel, asymmetric Bragg crystal spectrometer/polarimeter array, developed by R. Graham Bingham is reported to enable simulaneous spectrometry and high precision polarimetry in selected energy channels. Each spectrometer/polarimeter consists of an X-ray concentrator/detector unit which could be cycled into the X-ray telescope beam. The method measures linear polarization by comparing counting rates of individual sectors of an X-ray sensor located at a collecting cone apex.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. W 74-70630 (188-41-59) X-ray Astronomy, Elihu Boldt, GSFC, Ph. (301) 982-5853.

b. W 74-70631 (188-41-59) X-ray Astronomy, N. G. Roman, Ph. (202) 755-3649.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Symmetric nonpolarized X-ray telescope.
b. Development of X-ray instrument mounts allowing rotation in a circle around X-ray telescope FOV center.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-2.3-2

1. TECHNOLOGY REQUIREMENT (TITLE): X-ray Polarimeter PAGE 3 OF 3
Sensitivity; dimensional stability

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Parametric Analysis	—																		
2. Predesign & Fab.	—	—																	
3. Test & Evaluation		—	—																
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)				—	—														
2. Devl/Fab (Ph. D)						—	—												
3. Operations										T1	•	•		•		•	•		
4.							T2	o	T3	o	T4 —	—	—	—	—	—	—		

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				T														
NUMBER OF LAUNCHES								T2	T3	T2	T1	T1 T4		T1		T1	T1	9

14. REFERENCES:

a. Final Report of Space Shuttle Payload Planning Working Groups, NASA/GSFC, May 1973, pages A-1, -2, -4.
b. Summarized NASA Payload Descriptions, Sortie Payloads, Level A Data, July 1974, pages 112 - 115.
c. Summarized NASA Payload Descriptions, Automated Payloads, Level A Data, July 1974.
d. Payload Descriptions, Vol. I, Automated Payloads, Level B Data, NASA, July 1974.

Legend
T = Technology
• = Sortie Operations
— = Automated Operations
T1 = HE-19-S, Low Energy X-ray Telescope
T2 = HE-20-S, High Energy X-ray Telescope
T3 = HE-11-A, Large High Energy Observatory D (1.2m X-ray Telescope)
T4 = HE-01-A, Large X-ray Telescope Facility

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.4

1. TECHNOLOGY REQUIREMENT (TITLE): Position Sensitive Proportion Counter — Spectral resolution, spatial resolution, transient measurements PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Measure source spectra to $\lambda/\Delta\lambda = 5$, spatial resolution to 0.2mm and transients measured to 1 μsec in spectral range to 0.124 to 6.2 keV.

4. CURRENT STATE OF ART: Spectral distribution to $\lambda/\Delta\lambda = 1$, spatial distribution to 1 mm and transient measurement to 10 μsecs.

HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY

Position sensitive proportional counters are intended for measurement of structure of diffuse backgrounds and coronal of near by stars. Early position sensing proportional counter concepts include one using multianode resistive wire grids. The input signal components are measured by comparing the charge collected at the two ends of each wire. The orthogonal component is determined by the identity of the wire collecting the charge To get 10 arc sec resolution over a 1° field, approximately 360 anode wires spaced 10 arc sec apart in an X-ray telescope field are required. Considerable electronics are required for anticoincidence, pulse height analysis, count per analyzer, position reporting, & event timing.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Early position sensitive proportional counters have been designed. Advanced matrices will have more position sensing elements. Earlier telescopes did not have the resolution of planned telescopes.

b. HE-20-S, High Resolution X-Ray Telescope, HE-11A, 1.2m X-Ray Telescope and HE-01-A, Large X-Ray Telescope Facility utilize the position sensing porportional counter. However two other types of telescopes could utilize the position sensitive proportional counter if instruments are exchanged.

c. Flux and spectral distribution versus position and time could be obtained by the position sensitive proportional counter at input signal sensitivities approaching 10^{-8} Sco X-1 enabling quick mapping of a region.

d. When a position sensitive proportional counter is used with a Large X-ray Telescope at sensitivities approaching 10^{-8} Sco X-1, the ultimate technology requirements will be satisfied. However initial test should be performed in space.

TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.4

1. TECHNOLOGY REQUIREMENT(TITLE): Position Sensitive Proportional Counter — Spectral resolution, spatial resolution, transient measurement PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

Wire grid proportional counters may compete with solid state detector arrays complemented with microchannel plate circuits. Improved imaging devices compete or do better in spatial position but tend to lack spectral resolving ability. Proportional counters are best used in the 0.1 to 30 keV region. The low energy end of the range is deremined primarily by the counter window while photoelectric efficiency determines the highest energy at which the counter can give useful information. An argon counter is best suited for 1 to 10 keV, propane or other gases are utilized for lower energy/ranges to enable quenching.

It appears that a solid state alternate to the wire grid proportional counters will have a better transient response than the wire grid gas proportional counter type.

8. TECHNICAL PROBLEMS:

a. Gaseous wire grid instruments tend to have long collection times hence limiting timing accuracy.
b. Solid state detectors used in arrays equivalent to proportional counters tend to have lesser spectral range than wire grid proportional counters.

9. POTENTIAL ALTERNATIVES:

a. Multisegmented solid state detector.
b. Parallel plate proportional counter. (Stumpel, Sanford, and Goddard, Journal of Physics E, 6, 397, 1973.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP: W74-70630 (188-41-59) X-ray Astronomy, Elihu Boldt, Ph (301) 982-5853, GSFC.

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Development of X-ray collectors (telescopes) for concentrating X-ray images on position sensitive detector array.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-2.4

1. TECHNOLOGY REQUIREMENT (TITLE): Position Sensitive Proportion Counter – Spectral resolution, spatial resolution, transient measurements PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Trades & Analysis	—																		
2. Design & Fab.	—	—																	
3. Test & Evaluation		—	—																
APPLICATION																			
1. Design (Ph. C)				—	—														
2. Devl/Fab (Ph. D)						—	—												
3. Operations										T1	•	•		•		•	•		
							T2	•		•									
								T3	—	—	—	—	—						
											T4	—	—	—	—	—	—		

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				T														
NUMBER OF LAUNCHES								T2	T3	T2	T1	T1 T4		T1		T1	T1	9

14. REFERENCES:

a. Final Report of Space Shuttle Payload Planning Working Groups, NASA/GSFC, May 1973, pages A-1, -2, -4.

b. Summarized NASA Payload Descriptions, Sortie Payloads, Level A Data, July 1974, pages 112-115.

c. Summarized NASA Payload Descriptions, Automated Payloads, Level A Data, July 1974.

d. Payload Descriptions, Vol. I, Automated Payloads, Level B Data, NASA, July 1974.

Legend:
T = Technology
• = Sortie Operation
—— = Automated Operations

T1 = HE-19-S, Low Energy X-ray Telescope
T2 = HE-20-S, High Energy X-ray Telescope
T3 = HE-11-A, Large High Energy Observatory D (1.2m X-ray Telescope)
T4 = HE-01-A, Large X-ray Telescope Facility

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

C 2

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.5

1. TECHNOLOGY REQUIREMENT (TITLE): Modulation Collimated Scintillation Counters; Flux distribution, spatial resolution, transient measurement PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Modulation collimated scintillation counting in 20 to 30 keV range to 2 arc sec resolution in field of view of 5×5°. A collector area greater than 10^4 cm^2 in a low background configuration is desired.

4. CURRENT STATE OF ART: HEAO A has a modulation collimator of 10 arc seconds resolution under development by American Science and Engineering, Smithsonian Astrophysical Observatory, M.I.T. HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

The scintillation counter with modified modulation collimators will need an improved modulation geometry and possibly temperature controlled grids. According to S. S. Holt, NASA GSFC, modulation collimators limit the field of view in either an integral or differential manner. An integral collimator cuts off the edges of the field of view and allows some response in the control field of view; integral collimators are good for angles >1/2 deg. Differential modulation collimators provide better source locations. Differential modulation collimators slice the field of view as well as limit the periphery of detector response to avoid other interfering sources. Hence, a given source may, within certain size and complexity limits be, mapped spatially as well as each spatial element categorized spectrally.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. An array of seven modules of 0.5 m dia × 1.5 m long has been proposed with about 1 meter of each unit consisting of the desired modulation collimators. A collector/slat/grid trade will provide highest collection efficiency and best coupling to scintillation counters.
b. HE-11-S, X-Ray Angular Structure, and HE-18-S, Gamma Ray Photometric studies are sortie payloads benefitting from this technology.
c. The development of high resolution modulation collimated scintillation arrays will enable imaging or determination of shape of extended X-ray sources, mapping of selected X-ray regions, and measurement of K and L absorption edges.
d. Acceptable maturity level is test in a space equivalent environment.

TO BE CARRIED TO LEVEL 7

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1. TECHNOLOGY REQUIREMENT(TITLE): Modulation Collimated Scintillation Counters; Flux distribution, spatial resolution, transient measurement

7. TECHNOLOGY OPTIONS:

Modulation collimators have been constructed of rectangular tubing, slats, wires, grids, or combinations thereof. Wires and grids need to have collimating dimensions in the order of 0.025 mm. Some of the collimators proposed would roll or oscillate over detector arrays or are fixed. The fixed configurations depend upon mount motion and spacing of scanning modes to give a relative motion effect between X-ray/gamma ray sources, modulation collimator, and detectors. The counting rate maxima and minima are then observed to define the source location to the order of arc seconds. Scintillators are expected to be used at energies in excess of 10 keV to detect flux and spectrum of X-ray sources versus spatial location. Pulse counting/energy measurement modes are contemplated.

8. TECHNICAL PROBLEMS:

a. Scintillators have poorer spectral (energy) resolution than do proportional counters but might be improved by use of scintillator-avalanche diode combinations.
b. Other than large collector scintillator cell areas shielded from interference by some forms of collimators, little can be done to concentrate or intercept enough of higher energy X-ray photons. Observing times may be long, up to days.

9. POTENTIAL ALTERNATIVES:

a. Development of spatial detector arrays made of X-ray to light or electron converter elements + microchannel plates. (Silicon or pure germanium lithium drift process, or avalanche detectors + tunnel diode.)
b. Arrays of combinations of scintillator cells + silicon or GaAs photoconductors.
c. Scintillators with isoelectronic dropouts (CdS with Te and ZnTe) or scintillators using Lanthanum oxysulfide & Gadolinium oxysulfide activated with Ytterbium or Cèrium.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. W74-70630 (188-41-59), X-Ray Astronomy, NASA/GSFC, Elihu A. Boldt (301) 982-5853.
b. W74-70635 (188-41-64), X-Ray Spectroscopy for Shuttle, NASA/GSFC, Elihu A. Boldt, (301)982-5853.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Development of scintillator and avalanche or photomultiplier detector combinations.
b. Combination of modulation collimator arrays and spatial detector (fast response) arrays in equivalent focusing (gating) modes as to obtain electronic scan and direction sensing ability.
c. Precise slow scanning capabilities are needed for the instrument pointing system or stabilized platform to enable sufficient integration of X-ray photons per spatial and spectral element as well as attainment of the desired spatial resolution.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C.2.5

1. TECHNOLOGY REQUIREMENT (TITLE): Modulation Collimated Scintillation Counters, Flux distribution, spatial resolution, transient measurement — PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

SCHEDULE ITEM (CALENDAR YEAR)	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Concepts Trades & Anal.	—																		
2. Prototype Design & Fab.	—																		
3. Tests & Evaluation		—																	
4. Redesign, Fab. & Test		—	—																
5.																			
APPLICATION																			
1. Design (Ph. C)			—	—															
2. Devl/Fab (Ph. D)				—	—	—													
3. Operations					T1	•		•		•		•		•		•			
4.								T2	•		•		•		•		•		

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE			T															
NUMBER OF LAUNCHES						T1		T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	11

14. REFERENCES:

a. Summarized NASA Payload Descriptions, Sortie Payloads, July 1974, NASA/MSFC, page 96.

b. Final Report of the Space Shuttle Payload Planning Working Groups, High Energy Astrophysics, May 1973, NASA/GSFC, pp. 36-37, A-11 to A-12.

c. Introduction to Experimental Techniques of High-Energy Astrophysics, NASA SP-243, 1970, pp. 91-2.

d. Materials for Radiation Detection, NMAB 287, January 1974, pages 47 through 78.

Legend

T: Technology

— = Automated Operations

• = Sortie Operations

T1 = HE-11-S, X-Ray Angular Structure

T2 = HE-18-S, Gamma-Ray Photometric Studies

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-2.6

1. TECHNOLOGY REQUIREMENT (TITLE): CONVERTER/INTENSIFIER ASSEMBLY

2. TECHNOLOGY CATEGORY: Sensor

3. OBJECTIVE/ADVANCEMENT REQUIRED: Provide high resolution, variable F.O.V. sensor for energy range 0.3 to 1 KeV

4. CURRENT STATE OF ART: Photon and charged particle imaging systems are available for soft X-rays within the energy range of interest. Resolution needs to be increased for this application. HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

Imaging data of X-ray sources is required in the range 0.3 to 1 KeV, with a spatial resolution of 1024 x 1024 elements per frame, and 8 bits/element. Two selectable fields of view are required: $0.3^{o} \times 0.3^{o}$ and $5^{o} \times 5^{o}$. Electronics must be capable of controlling, testing, converting, scaling, formatting the data to and from the X-ray telescope and converter/intensifier.

The problem of X-ray photon detection and localization can be divided into three functions -- photoelectric conversion, charge amplification, and charge detection and localization. One component, such as a microchannel plate, may be used for more than one function, for example, photoconversion and charge amplification in this case.

(Continued on page 2)

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) The scientific basis for this technology requirement is the need for data on the fine structure of X-ray sources, as defined by the Space Shuttle Payload Working Group in terms of the wide field X-Ray telescope payload.

(b) The benefitting payload will be HE-03-A, 0.75 meter X-Ray telescope.

(c) More detailed perception of flux density and angular position will enable better identification of key characteristics and special features of soft x-ray sources.

(d) This development should include the development of a prototype sensor model to be tested in a sounding rocket or small satellite survey mission.

TO BE CARRIED TO LEVEL 7

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5. DESCRIPTION OF TECHNOLOGY (CONT'D)

An important X-ray imaging device currently being developed is the negative electron affinity photocathode (VanSpeybroeck, Kellogg, Murray, and Duckett, IEEE-Transaction on Nuclear Science NS21, 408, 1974), which theoretically should be a factor of 5 to 10 times more efficient in the photoconversion process at 1 - 4 keV than currently observed, or theoretically expected from other photo-emitters, such as the walls of a Micro-channel Plate. The photoelectron signal must then be amplified and detected. The microchannel plate devices are suitable amplifiers, and the charge detector can be one of a number of devices, some of which are discussed in the paper by Lampton and Paresce which describes the "Ranicon".

At least two charge detection schemes are being developed - one based on a sheet resistor such as in the "Ranicon"* - in which two dimensional charge diffusion occurs, and one based upon charge splitting techniques, in which each coordinate is determined independently (charge diffusion occurs in two separate one dimensional devices). The best results obtained with the two dimensional devices are those of the University of Leicester group - σ of about 18μ over an 18 mm field, or one part in 1000. This is to be compared with the Ranicon result of 1 - 2 lp/mm limiting resolution, or σ= 400 to 200μ over a field of 4 cm, or one part in 100 - 200. The SAO HEAO-B group has achieved the best result obtained with the charge splitting technique (known to us) - σ of about 50μ , with, however, no practical intrinsic size limitation because systems easily can be operated in parallel to cover larger areas without boundary losses. This system performance also was obtained with a wide dynamic range of input amplitudes, which is required for one of the detectors being developed. This is possible because the fractional resolution needn't be good.

The French have developed a different approach, which consists of a multi-wire proportional counter containing an ionization chamber. A matrix of 30,000 anode wires collects ions created by X-ray photons. Each anode is followed by an amplifier, trigger, counter, and memory. Readout of the memory can be effected 10 times per second.

*Developed by Michael Lampton and Francesco Paresce, at Berkeley.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-2.6

1. TECHNOLOGY REQUIREMENT(TITLE): CONVERTER/INTENSIFIER ASSEMBLY

7. TECHNOLOGY OPTIONS:

(a) The pulse position determination method may involve options such as "successive digital approximation", dual slope integrator, leading edge rise time, etc.

(b) Flat Plate Proportional Counter (Stumpel, et al)

8. TECHNICAL PROBLEMS:

The principal problem is attaining the high spatial resolution within the sensitivity limitations of the source.

9. POTENTIAL ALTERNATIVES:

Should consider the Negative Electron Affinity Photocathode with a charge amplification stage and either the charge splitting, separate coordinate determination or a sheet resistor charge detector. The microchannel plate and sheet resistor should be considered a potential alternative during the period required to develop the higher sensitivity device. Other potential alternatives also exist.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP #188-41-59 - X-Ray Astronomy
RTOP #188-41-64 - X-Ray Spectroscopy for Shuttle

(NOTE: These are related efforts, not dealing directly with the requirements of this definition

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

The possibility of using delay lines to scan large number of elements in the proportional counter has been investigated. This method has shown promise for low resolution one and two dimensional imaging.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-2.6

1. TECHNOLOGY REQUIREMENT (TITLE): CONVERTER/INTENSIFIER ASSEMBLY

PAGE 4 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analyses	—																		
2. Laboratory Tests		—																	
3. Breadboard Tests			—																
4. Prototype Design				—															
5. Rocket Tests					—														
APPLICATION																			
1. Design (Ph. C)					—														
2. Devl/Fab (Ph. D)						—													
3. Operations						—	—	—	—	—	—	—	—	—	—	—	—		
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					△													
NUMBER OF LAUNCHES						1	1	1	1	2	2	2	1	1	1	2	2	17

14. REFERENCES:

"The RANICON: A Resistive Anode Image Converter," by Michael Lampton and Francesco Paresce, Review of Scientific Instruments, Sept. 1974.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. C.2.7

1. TECHNOLOGY REQUIREMENT (TITLE): Echelle Spectrograph — PAGE 1 OF 4

Spectral Resolution; Dimensional Stability; Imaging detector sensitivity

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Spectral resolving power of 10^5 in 120 to 700 nm range; Echelle format for imaging efficiency; higher sensitivity detectors

4. CURRENT STATE OF ART: A resolving power of 10^4 has been achieved in the middle UV per Space Optics, by Thompson & Shannon, NBS, 1974, pp. 319

HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY: A modified echelle spectrograph/spectrometer (consisting of several instruments in one assembly) is desired to cover the 120 to 700 nm spectral range. Extension of UV coverage from 120 nm to 90 nm is desired. The echelle arrangement allows a spectral band length (up to 10 meters long) to be read out in spectral strips folded like lines of type on a printed page. Each portion of the spectrometer has its own set of optics including predisperser, echelle grating, focusing mirror, and camera. The mirror, grating ratings, film or imaging device, and coatings are selected per spectral wavelength range. Detector sensitivity needs improvement to enable high resolution spectrograms to be obtained at fainter source brightnesses.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☒ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Echelle spectrometers have been used in aircraft (O'Dell, in Lear Jet, etc) and in sounding rockets. Hence, an orderly history of development exists to provide a base technology. Interferometric techniques for ruling gratings as well as better ruling engines exist.

b. The development of echelle spectrometers of high resolving power with sensitivity to reach moderate brightness stars would lead to use of these instruments in AS-01-A, Large Space Telescope, AS-04-S, 1m Diffraction Limited UV-Optical Telescope, AS-14-A, 1m UV-Optical Telescope (1), SO-01-S, Dedicated Solar Sortie Mission (DSSM), SO-02-A, Large Solar Observatory. The first three are astronomy payloads, the last two are solar; some degree of commonality may exist.

c. The echelle spectrographs enable attainment of complete spectral signatures of elements emitting radiation in the sources examined as well as ability to identify and, in data reduction, reject absorption lines of interspace clouds. Also they enable one to study narrow spectral lines and determine abundance in each cloud rather than integrated abundance along the line of sight. High resolution spectra of areas on the sun or of stars enable estimation of constituents in the area observed as well as measures of temperatures.

d. Final test would occur on a shuttle sortie mission in conjunction with a 1m telescope such as AS-04-S. An Aries launched rocket flight would meet the initial technology requirement.

TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C.2.7

1. TECHNOLOGY REQUIREMENT(TITLE): Echelle Spectrograph PAGE 2 OF 4

Spectral Resolution; Dimensional Stability; Imaging Detector Sensitivity

7. TECHNOLOGY OPTION In spectrograph design analysis, a balance between parameters such as spectral resolution, spectral range per exposure, field of view, and mechanical complexity is necessary. To obtain full resolution from the echelle spectrometer, each of the parameters may be driven to the state of art limit. Some idea of complexity may be seen from the following description. "The main light beam, after passing through a slit is split spectrally into 3 light beams. Three predisperser gratings mounted on a platen which can be translated into indexed positions bring the appropriate predispersers into their corresponding light beams and the predisperser collimates light from the slit into the proper echelle grating and restricts wavelength remaining to a single order." Automatic alignment and adjustment for each of the spectral ranges may be possible. A higher sensitivity, lower noise level detector is desired for use with automated payloads. In sortie use, film is expected to be used. For applications to solar astronomy, detectors with very large dynamic range will be needed. The primary discussion here dealt with astronomical echelle spectrographs.

8. TECHNICAL PROBLEMS:

a. Requires advances in coatings, particularly in the 200 to 120 nm range to avoid destructive interference effects.
b. It is easier to achieve the higher spectral resolution by increasing instrument size if adequate structural stability can be maintained; hence instrument size tends to grow.
c. Stray light control.
d. Grating fineness, uniformity, and degradation of reflecting surfaces. (Related work is going on at GSFC in development of laser holographic gratings; the laser holographic gratings may be applicable over wide wavelength ranges.)

9. POTENTIAL ALTERNATIVES:

a. A series of Fabry Perot spectrometers can be used to cover the total spectral range; however more instrument sections may be required.
b. Fourier interferometers might be possible in the visible and UV ranges since stable laser references, better detectors and optics now exist.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. W74-70619 (188-41-51), UV and Optical Astronomy, GSFC, Albert Gobbess, (301) 982-5103.
b. W74-70627 (188-41-55), Ultraviolet Stellar Spectrometer Development, NASA/JSC, Y. Kondo, (714) 483-646[illegible].
c. W74-70634 (188-41-64), Astronomy Sortie Instruments, NASA/GSFC, T. P. Strecher, (301) 982-4718.
d. W74-70660 (188-78-56), Optical Instrumentation - Image Tube Development, NASA, Washington, D. C., M. J. Aucremanne, (202) 755-3676.

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

a. A telescope with an input angular resolution of 0.1 arc sec is desired.
b. Absolute pointing accuracy and vernier adjustment to 0.1 arc sec plus slit jaw equivalent monitor capability is desired.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C.2.7

1. TECHNOLOGY REQUIREMENT (TITLE): Echelle Spectrograph PAGE 3 OF 4

Spectral Resolution; Dimensional Stability; Imaging detector sensitivity

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY: 1. Trades & Analysis 2. Imprvd. Model Des. & Fab 3. Test & Evaluation																			
APPLICATIONS: 1. Design (Ph. C) 2. Devel./Fab. (Ph. D) 3. Operations					T3 T2	T5			T1	T4									

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	Total
TECHNOLOGY NEED DATE			T															
NUMBER OF LAUNCHES						T2 T3	T5 T3	T3	T2 2T3	T1 T5 2T3	2T1 T4 3T3	3T1 2T3	3T1 T5 3T3	4T1 T2 2T3	3T1 3T3	3T1 2T3	4T1 3T3	56

14. REFERENCES:

a. Large Space Telescope Phase A Final Report, Volume IV - Scientific Instrument Package Nasa TMX-64726, December 1972, MSFC, pp. 3-22 to 3-26.

b. Summarized NASA Payload Descriptions, Sortie Payloads, July 1974, NASA/MSFC, pp. 34,120.

c. Summarized NASA Payload Descriptions, Automated Payloads, July 1974, NASA/MSFC, pp. 22,60.

d. Orbital Astronomy Support Facility (OASF) Study, Volume II, Part 1, Douglas Missile and Space Systems Division, DAC-58142, June 1968, p. 373.

e. Large Space Telescope Optical Telescope Assembly/Scientific Instruments Phase B Definition Study, Itek Optical Systems Division, Contract NAS8-29949, December 1973, LST-74-10, pages 6-14.

f. Large Space Telescope Optical Telescope Assembly/Scientific Instruments Phase B Definition Study, Itek Optical Systems Division, Contract NAS8-29949, January 1974, LST-74-27, pages 1-2 to 1-4.

g. Orbital Astronomy Support Facility (OASF) Study, Vol. III, Book 1, Douglas Missile and Space Systems Division, DAC-58143, June 1968, pp. 143-45.

h. Reference Earth Orbital Research and Applications Investigations (Blue Book), Vol. II - Astronomy, Jan. 1971, NASA NHB 7150.1, pp. 2-17 to 2-18, 3-17.

Legend: See page 4.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C.2.7

1. TECHNOLOGY REQUIREMENT (TITLE): Echelle Spectrograph PAGE 4 OF 4
Spectral Resolution; Dimensional Stability; Imaging detector sensitivity

LEGEND:

T = Technology
● = Sortie Payload
— = Automated Payloads
T1 = AS-04-S, 1m Diffraction Limited UV Optical Telescope
T2 = AS-01-A, Large Space Telescope
T3 = SO-01-S, Dedicated Solar Sortie Mission
T4 = SO-02-A, Large Solar Observatory
T5 = AS-14-A, 1m UV Optical Telescope (automated version of AS-04-S)

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C.2.8

1. TECHNOLOGY REQUIREMENT (TITLE): VIS-IR Mapper / Sensor Assembly (SEOS), Improved Registration Accuracy; Instantaneous Field of View, Spectral Resolution

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Improvement in angular (spatial) resolution, detector coupling, and detector element packing density (angle to 3 μrad). Continual and random access to earth surface area within line of sight of synchronous orbit satellite.

4. CURRENT STATE OF ART: VSSR has effective angular resolution of 21 x 25 μrad in the visible portion of the spectrum and 14 μrad in the parallel mirror thermal window. HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY

A multi-band visible light/IR sensor assembly is planned to be used at earth synchronous altitude to provide multispectral imaging of the earth. The IR assembly is coupled to a 1.5 m telescope which collects IR image radiation components. Either linear mechanically scanned arrays or static image matrices will be used at the focal plane of the telescope. Angular resolution in the wavelength region between 0.5 to 15μm varies from 0.0027 mrad to 0.14 mrad with poorer resolution at the longer wavelengths. Desired ground resolution varies from 100 meters at 0.5 μm to 800 m at 15 μm. Up to 200 different channels, some narrow band imaging but some used in sets of spectral lines, to enable selective examination of each spatial sector in view of the synchronous orbit satellite are required.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Linear mechanically scanned arrays have been used on aircraft and some spacecraft. Equivalent static imaging matrices in the form of visible light and near IR image tubes have been used. However, a ground image resolution of 100 to 1500 m is desired with the multispectral imaging sensor in 35,870 km orbit which will require more detector elements in imaging arrays. Angular resolution of 4.85 μrad (1 arc sec) have been achieved in the visible light region by astronomical telescopes. GSFC is applying light weight astronomy telescope techniques to solving the synchronous orbit earth observation problem.

b. EO-09-A, Synchronous Earth Observatory Satellite, EO-57-A Foreign Synchronous Meteorological Satellite, EO-59-A Geosynchronous ERS and EO-62-A Foreign Synchronous EOS will benefit from improvement in angular resolution, detector coupling, and detector packing density.

(Continued on Page 2)

TO BE CARRIED TO LEVEL 8

1. TECHNOLOGY REQUIREMENT (TITLE): VIS-IR Mapper/Sensor Assembly (SEOS), Improved Registration Accuracy; Instantaneous Field of View, Spectral Resolution

6. RATIONALE AND ANALYSIS: (Continued)

c. The technology improvement will enable improved payload performance in obtaining meteorological (flood, storm, freeze, fog, pollution), oceanographic, land use, natural resources, and agricultural data. Changes and trends are more readily observed from a geostationary satellite. The initial satellite will enable earth observation technology development as well as useful observations. Later, a set of three applications satellites can provide random access observation of the whole populated earth.

d. Because of multiple needs of many groups and the limited launch capability to synchronous orbit, the resultant compromise SEOS Sensor Assembly will need to receive its final test in orbit. Earlier tests in the laboratory together with corrective action will be needed to develop the desired performance.

7. TECHNOLOGY OPTIONS: The objectives of best spatial and spectral resolution per earth surface and atmospheric location element for each spectral region capable of yielding chemical and physical characteristics information result in a large number of tradeable options. The location of the observing satellite at earth synchronous altitude enables an instantaneous view of about a 17 degree diameter area of the earth and the surrounding atmosphere. If the whole area were viewed by an imaging sensor at one selected wavelength band at best desired resolution about 2.94×10^9 spatial elements would need to be examined. Hence each circular frame would require many gigabits of data per frame. Since up to 200 spectral bandwidths need to be examined essentially simultaneous to a radiometer accuracy of at least 1%, most of the SEOS sensor options consider less than the total available field of view.

A compromise SEOS sensor assembly might cover a field of view of $0.5 \times 0.5^{\circ}$ (1800 x 1800 arc seconds) with an instantaneous field of view of 0.003 millirad or better with the observation telescope output image being imaged at any 4 or 5 spectral bands out of 24 to 200 bands at one time. The telescope would be capable of being pointed to any 0.5 by 0.5° sector within the surface area of the 17° diameter earth scene available by direct line sight from synchronous altitude.

Body pointing of a narrow field telescope versus selection of part of the field of view of a wider field telescope needs to be considered in trade studies as well as from a state of art viewpoint. A wide field telescope could observe the whole earth's surface at one time; auxiliary switchable optics could select any desired sector more quickly than slewing the telescope.

(Continued on Page 3)

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 2.8

1. TECHNOLOGY REQUIREMENT (TITLE): VIS-IR Mapper/Sensor Assembly (SEOS), Improved Registration Accuracy; Instantaneous Field of View, Spectral Resolution PAGE 3 OF 5

7. TECHNOLOGY OPTIONS: (Continued)

Major options needing trade analysis and research are those involved in development of an advanced multiple band selector process that would enable simultaneous imaging in up to 5 spectral bands selected from a total of 24 to 200 spectral bands. A dynamic range better than 256 with a radiometric accuracy of better than 1% per spatial resolution element is desired. Area and spectral band selection flexibility should predominate in these analyses.

To satisfy the need for random spatial and spectral access anywhere within line of sight of a SEOS, careful consideration of all detector configuration options is necessary. Scanned linear arrays versus static multispectral imaging arrays and the role of tunable imaging filters need research, particularly where a number of images at a number of selectable spectral bands needs to be acquired at the same time.

Up to 40,000 detectors per linear array and up to 5 linear arrays in a push broom configuration might be possible; imaging arrays may grow from 0.262 million image elements to 400 million image elements per spectral band.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C.2.8

1. TECHNOLOGY REQUIREMENT(TITLE): VIS-IR Mapper/Sensor Assembly (SEOS), Improved Registration Accuracy; Instantaneous Field of View, Spectral Resolution

8. TECHNICAL PROBLEMS:

a. High array density and high transfer efficiency.
b. Noise due to slow response of high density detector arrays.
c. Trade between mechanically scanning multiple linear detector arrays and static IR imaging devices.
d. Image indexing to 0.1 to 0.5 resolution element; landmark recognition to supplement stellar referencing.
e. Insufficient radiance per band for small spatial surface elements.
f. Weight delivery to synchronous orbit is limited.
g. Scattered light and stray light suppression.
h. Direct solar radiation suppression.
i. Calibration accuracy of 1% over large, multielement detector arrays.
j. Cooling for IR detectors.

9. POTENTIAL ALTERNATIVES:

a. Far infrared vidicons with filters for some of the bands.
b. Pyroelectric vidicon in place of cooled detector arrays.
c. Silicon charge-coupled devices (has problem of loss of incoming signal at high input levels).
d. Cluster of telescopes each with sets of sensors to cover each sector.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. W74-70488 (177-22-41), Visible and IR Sensors Subsystems, NASA/GSFC, Harvey Ostrow, (301) 982-4107.
b. W74-70489 (177-22-81), Visible-Infrared Sensor System Technology Development, NASA/JSC, Richard R. Richard, (713) 483-4661.

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Stabilization of input by 1 to 1.5m telescope used for observing the earth.
b. Efficient coupling of visible and IR radiation to linear or matrix detector array.
c. Light weight temperature insensitive telescope optics.
d. On board data correlation and processing versus multiple wideband communication links from synchronous orbit satellite to a dedicated earth based communication terminal.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. C.2.8

1. TECHNOLOGY REQUIREMENT (TITLE): VIS-IR Mapper/ Sensor Assembly (SEOS), Improved Registration Accuracy; Instantaneous Field of View, Spectral Resolution — PAGE 5 OF 5

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Options & Parametric Analysis																			
2. Design imaging sensor																			
3. Construct model																			
4. Test model																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations						T1 T2							T3 T4						

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	Total
TECHNOLOGY NEED DATE				T														
NUMBER OF LAUNCHES							T1 T2	T2	T1	T2	T1	T2	2T1	T2 2T3 T4	2T1 2T4	T2 2T3	2T1 T4	23

14. REFERENCES:

a. Summarized NASA Payload Descriptions, Automated Payloads, July 1974, NASA/ MSFC, pp. 84, 92, 96, 100.

b. Payload Descriptions, Vol. 1, Automated Payloads, Level B Data, July 1974, NASA/MSFC, pp. 5-24, 5-78.

c. Advanced Scanners and Imaging Systems for Earth Observations, December 1972, NASA SP-335, pp. 71-180.

d. Comments, R. F. Hummer, Santa Barbara Research Center, 31 Dec. 1974.

Legend:

— Automated Operations

T Technology

T1 = EO-09-A, Synchronous Earth Observatory Satellite

T2 = EO-57-A, Foreign Synchronous Met. Sat.

T3 = EO-59-A, Geosynchronous ERS

T4 = EO-62-A, Foreign Synchronous EOS

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C2.9

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Thematic Mapper Registration Accuracy PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Registration accuracy within 0.3 picture element (pixel). Precise correlation of multispectral data to a single picture element.

4. CURRENT STATE OF ART: Registration accuracy is within 3 pixels.

HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY: Mapping is required to identify terrestrial features for map making, land use planning, hydrological and agriculture purposes with 10 to 30 m resolution. The advanced thematic mapper may have 7 to 12 spectral bands. The detector output for each band must be capable of being registered within 0.1 pixel with the output of any other detector. This requires sampling the output of all detectors systematically and keeping the resultant data as a recognizable set. Also, the output of a side looking radar must be registered with the thematic mapper outputs within a single picture element. In addition, images need to be registered accurately from pass to pass over the same ground area. Landmark references are needed to enable registration of image outputs. Stellar referencing helps if correlated with landmark references.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Registration of data from detectors associated with the separate bands of an IR Scanner can be achieved easily by sampling all detector outputs at the same time. Registering IR scanner data with that of another instrument(the side looking radar) is much more difficult.

b. Benefitting payloads are: EO-08-A, Earth Observatory Satellite, EO-61-A, Earth Resources Survey Operational Sat., OP-02-S, Multifrequency Radar Land Imagery, OP-05-S, Multispectral Scanning Imagery.

c. Accurate multispectral image registration will allow more effective land use determination for planning purposes.

d. Technology objectives can be demonstrated by flying a model of the instruments in an aircraft.

TO BE CARRIED TO LEVEL 6

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C2.9

1. TECHNOLOGY REQUIREMENT(TITLE): Thematic Mapper (Advanced) PAGE 2 OF 3
Registration Accuracy

7. TECHNOLOGY OPTIONS: Registration within one instrument between images in different spectral bands can be achieved by sampling all detectors concurrently. Registering images from different instruments requires very accurate alignment and synchronization in pointing angle and time of recording data. Seven to 12 spectral bands in the range from 0.5 to 15 μm are expected. One can obtain both high resolution and high sensitivity for a given collector size by scanning several lines in parallel.

The high resolution requires a small I FOV which means the detector must be very sensitive but response time must also be sufficient for the scanning rate. There is a tradeoff between spatial resolution and IR input temperature sensitivity (higher resolution reduces sensitivity). An accurate calibration source should be provided for the IR scanner.

8. TECHNICAL PROBLEMS:

a. Accurate optical alignment of separate instruments.
b. High resolution requires small I FOV and high detector sensitivity. (Ideally collector size is determined by the resolution requirements and detector sensitivity.)
c. Detector response time may be a problem at high scan rates.
d. High data rates and large amount of total data.

9. POTENTIAL ALTERNATIVES:

a. Accurately record pointing angles with data and register images by postflight computer processing. Use landmark recognition as well as stellar references.
b. Build single instrument with accurately controlled FOVs for IR and radar. However, radar and scanner geometry is different.
c. Use reference such as a laser beam pointed by radar and identifiable in IR image from reference beacons.
d. Use of laser heterodyne radiometry.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. W74-70488 (177-22-4), Visible and IR Sensors Subsystems, NASA/GSFC, Harvey Ostrow, (301) 982-4107.
b. W74-70489 (177-22-81), Visible-Infrared Sensor System Technology Development, NASA/JSC, Richard R. Richard, (713) 483-4661.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Develop a high resolution thematic mapper.
b. Develop a high resolution side looking radar.
c. Resolve onboard data correlation and processing versus communication relay link (TDRS) data problem.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C2.9

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Thematic Mapper Registration Accuracy PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
Technology:																			
1. Options & Param. Analysis																			
2. Design Model																			
3. Build Model																			
4. Test Model & Evaluate																			
Application:																			
1. Design (Phase C)																			
2. Devel./Fab. (Phase D)																			
3. Operations				T1 T2															
13. USAGE SCHEDULE:				T3 T4		●● ●●	●● ●●	●● ●●	●● ●●	● ●	● ●	● ●	●● ●●	●● ●●	●● ●●	● ●	● ●		
TECHNOLOGY NEED DATE		T																	Total
NUMBER OF LAUNCHES					2	6	6	6	5	4	3	4	6	5	6	3	4		60

14. REFERENCES:

a. Summarized NASA Payload Descriptions, Automated Payloads, Level A Data, July 1974, NASA/MSFC.

b. Summarized NASA Payload Descriptions, Sortie Payloads, Level A Data, July 1974, NASA/MSFC.

c. Earth Resources Payload for the Spacelab, MBB-ERP 73/02, Dec. 1973, pp. 114-17.

d. Comments from H. Tavares, Honeywell Radiation Center, Lexington, Mass., 30 Dec. 1974.

e. Comments, R. F. Hummer, Santa Barbara Research Center, 31 Dec. 1974.

Legend:

T Technology

● Sortie Operations

__ Automated Operations

T1=EO-08-A, Earth Observatory Satellite

T2=EO-61-A, Earth Resources Survey Operational Sat.

T3=OP-02-S, Multifrequency Radar Land Imagery

T4=OP-05-S, Multispectral Scanning Imagery

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.10

1 TECHNOLOGY REQUIREMENT (TITLE): VIS-IR Mapper, Luminescence Mapper -- Coastal zone fluorescence measurement with scanning spectral radiometer; Spectral resolution PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Measure reflectance and emission spectra in the visible region to single Fraunhofer lines; attain image resolution of 100 to 300m in ±22.5° swath widths from altitudes up to 1695 km.

4. CURRENT STATE OF ART: At present spectral resolution good to one Fraunhofer line in a wide angle scanning instrument has not been attained but high potential exists.

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

Promising development in the field of luminescence mapping appears feasible with new instruments that make measurements within several "single" Fraunhofer lines and may push the "state of art" sensor development. The effective instantaneous field of view (EIFOV) desired in the ocean coastal environment is between 3 and 300 meters. In general, the use of ocean color to monitor currents, biological, and ecological features requires high sun elevation angles and a scan that looks away from the sunside of the spacecraft. A sensor system capable of observing the oceans up to 20 deg away from nadir enhances contrast of ocean features at space altitude. Up to 3 Fraunhofer lines in the IR and 6 lines in the visible UV portion of the spectrum appear amenable.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. The information extracted from scanner data is in the spatial, spectral, and temporal distribution of radiation from an ocean scene. For the most part, attention has been given to improving spatial resolution. More recently considerable attention has been given to spectral distribution and automatic classification based on the spectral information from the scene. Finally the advanced ocean scanning spectrometer developed will be a high resolution multispectral scanner with ability to observe a given ocean area periodically.

b. The luminescence mapper is planned to be used as part of EO-56-A, Environmental Monitoring Satellite.

c. The desired performance will enable better sensing and application of ocean fluorescence components to detect, identify, and measure characteristics of river and ocean pollutants.

d. Technology requirements will be satisfied when a luminescence scanner is tested in a high altitude aircraft flight.

TO BE CARRIED TO LEVEL 6

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.10

1. TECHNOLOGY REQUIREMENT(TITLE): VIS-IR Mapper, Luminescence Mapper — Coastal zone fluorescence measurement with scanning spectral radiometer; ~~Spectral resolution~~ PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

Spectral and spatial resolution, signal to noise, and ocean surface fluorescence are parameters directly related to identifiability. Observation parameters such as observation angle, polarization &spectral bands need to be optimized. Narrow band filters at each of several Fraunhofer lines are needed to pass the instantaneous image of a set of ocean scanning optics to a photo multiplier or an imaging sensor. Trades between integrating image sensors, such as a vidicon, and scanned detector elements, such as avalanche diodes or charged coupled arrays, need to be made. Of course, depending upon the scanning optics, rotating or push broom linear arrays (one filter and a single Fraunhofer line per line of detectors) may be used.

8. TECHNICAL PROBLEMS:

a. Rapid scanning imposes high sensitivity requirements on the instrument design including use of better detectors.
b. Design of a Fabry Perot (<1Å) filter at each Fraunhofer line.
c. Optical scatter reduction.
d. Development of a catalog of fluorescence signatures enabling identification of pollutants and a measure of abundance of each pollutant.
e. Detector response.
f. Photomultiplier limiting noise.
g. Cooling photocathode to increase sensitivity.

9. POTENTIAL ALTERNATIVES:

a. Comparisons of signature data obtained by thermal IR, microwave sensors, and synthetic aperture radar to identify pollutants.
b. Multispectral Scanner (0.4-0.5 μm, 0.8-0.9 μm, 3.5-4.0 μm, 5-7 μm, 8-14.5 μm, etc)

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP W74-70545 (177-55-61) Physical Oceanography and Coastal Processes, including Marine Disaster, J.D. Oberholtzer (703-824-3411)

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Detectors Compatible with Fraunhofer line measurement devices.
b. Narrow band image pass filters such as Fabry Perot.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.10

1. TECHNOLOGY REQUIREMENT (TITLE): VIS-IR Mapper, Luminescence Mapper -- Coastal zone fluorescence measurement with scanning spectral radiometer; Spectral resolution PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90			
TECHNOLOGY																			
1. Parametric Analyses																			
2. Selection of Detectors																			
3. Assembly of Test Model																			
4. Flight Test (Hi Altitude Aircraft)																			
APPLICATION																			
1. Design (Phase C)																			
2. Devel/Fab (Phase D)																			
3. Operations																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
TECH START DATE																	
TECHNOLOGY NEED DATE		T															
NUMBER OF LAUNCHES						1	1	1			1	1	1	1		1	8

14. REFERENCES:

a. Summarized NASA Payload Descriptions, Level A Data, July 1974.

b. Advanced Scanners and Imaging Systems for Earth Observations, NASA SP-335, Dec 11-15, 1972, pages 15, 28, 32, 65, 244, 448.

c. J. A. Plascyk, Advanced Prototype Fraunhofer Line Discriminator, Perkin Elmer Report 1077A.

d. Comments, R. F. Hummer, Santa Barbara Research Center, Goleta, CA., 31 Dec. 1974.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.11

1. TECHNOLOGY REQUIREMENT (TITLE): VIS-IR Mapper for Coastal Zone Oceanography; Registration accuracy, IFOV reduction, spectral resolution PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Spectral data in 3 to 5 bands per spatial resolution element of 10m and 75m. (Development of technology enabling better coastal oceanography.)

4. CURRENT STATE OF ART: A resolution of 90m was obtained on Skylab; ERTS MSS achieved 75m spatial resolution with 4 spectral bands (0.5 to 1.1 μm)

HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY

The dual multispectral scanners (one with 10m ground resolution and the other with 75m resolution). The multispectral line scanners are used for coastal zone oceanography. Two scanners use various combinations of spectral bands, spatial resolution and field of view. The scanning section has an object plane scanner to take the load off the optical system and place it on a scanning system sequencing a narrow field of view across the ground trace of the flight path. Both a narrow field and wide field of view may be implemented on the same scanner assembly.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Rationale: Special oceanographic multifield of view scanner capable of spectral signatures appear feasible with some improvement in state of art in scanning, detectors, and data processing.

b. Benefitting Payloads: ST-22-S, ATL Payload No. 3 (Module + Pallet)

c. Justification: The purpose of the payload to demonstrate continually improved multispectral line scanner technology as well as other technologies can be satisfied by the technology development. Applications to continual improvement of other multispectral scanners are possible.

d. Technology Achievement Criterion: This technology development is satisfied for each successively improved multispectral time scanner by shuttle sortie flight test in orbit as per ST-22-S. Initial technology verification could be performed in a high altitude aircraft prior to demonstration in space. This advancement is a new capability based on an operational model with lower resolution capability, hence level 8.

TO BE CARRIED TO LEVEL 8

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DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.11

1. TECHNOLOGY REQUIREMENT(TITLE): VIS-IR Mapper for Coastal Zone Oceanography; Registration accuracy, IFOV reduction, spectral resolution

7. TECHNOLOGY OPTIONS:

While a four side wedge scanner may be used for 2 fields of view as a scanning device coupled into an all reflective Schmidt telescope, a Kennedy split field optical system is better. A reflecting polygon or a reverse polygon may be used. For limited spectral coverage, a refractive polygon with a rotating plane parallel plate is applicable. Other combinations with refractive wedges and Nipkow scanning devices also are possible. The S-192 multispectral scanner with a rotating pair of tilted mirrors in conjunction with their on-axis all-reflective Schmidt was used on Skylab. A Pfund type folding flat used with a spherical collector (U of Ariz) theoretically could provide 10 arc sec resolution over a 22 deg field of view. The Nipkow disk, refractive polygons, and wedges apparently cannot achieve 2.9 arc secs (10m resolution at 717 km). The only class of scanner that can meet the requirement appears to be an object space plane scan mirror with a highly corrected telescope working essentially on axis (such as in ERTS-1 MSS).

8. TECHNICAL PROBLEMS:

a. A multifield of view with two resolutions (greater signal at larger spatial resolution) needs to be indexed or correlated in registration at each of the spectral bands selected for oceanographic signatures.
b. Major problems include optical resolution, method of scanning, spatial registration (scan linearity, jitter, cross axis motion, position reference) accurate calibration, high data rate, and sufficiently sensitive detectors.

9. POTENTIAL ALTERNATIVES:

a. Electron beam imagers (extended to IR, coupled to wide field optics).
b. Solid State Sensor Arrays (self scanned, coupled to wide field all reflective optics).
c. Image Dissector Tube.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP W74-70546 (177-55-61) Physical Oceanography and Coastal Processes, including Marine Disasters, T.D. Oberhaltzer (703-824-3411)

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Output data rates up to 50 Mbps
b. Correction Tables: Correction versus altitude and angle from nadir.
c. Sensor Data System Hardware and Software (NASA SP335, page 418 to 565)

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-2.11

1. TECHNOLOGY REQUIREMENT (TITLE): VIS-IR Mapper for Coastal Zone Oceanography; Registration accuracy, IFOV reduction, spectral resolution PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90			
TECHNOLOGY								Successively Improved Versions											
1. Options & Parametric	—							—	—		—	—	—		—				
2. Design Optical System	—							—		—	—	—	—	—		—			
3. Assemble working model		—						—		—		—	—		—	—			
4. Test in space on sortie flight (initial test in aircraft)		—	—				●	—	—	—		—	—		—	—			
APPLICATION (Integration)																			
1. System Design Phase C			—	—															
2. Devel/Fab					—	—													
3. Operations							●		●	●		●	●		●	●			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
TECHNOLOGY NEED DATE		T															
NUMBER OF LAUNCHES							1		1	1		1	1		1	1	7

14. REFERENCES:

a. Advanced Scanners and Imaging Systems, Dec 11-15, 1972, NASA SP-335, pages 148 to 179, 183 to 301, 305 to 409.

b. Preliminary Summarized NASA Payload Descriptions, Sortie Payloads, Level A Data, July 1974.

c. Comments, R. F. Hummer, Santa Barbara Research Center, Goleta, CA, 31 Dec. 1974.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. C.2.12

1. TECHNOLOGY REQUIREMENT (TITLE): Scanning Spectroradiometer PAGE 1 OF 3
VIS-IR Instantaneous Field of View Reduction; Radiometric Accuracy

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Scanning with 29.4 to 44.2 microradian instantaneous FOV and sensing seven channels in the 0.5 to 1.1 μm, 1.55 to 1.75 μm, 2.1 to 2.35 μm and 10.1 to 12.6 μm bands with a radiometric accuracy of 3%

4. CURRENT STATE OF ART: Although 30 μ rad resolution has been achieved in the visible light and near IR regions, current instruments cannot meet requirement in 10.1 to 12.6 μm spectral region

HAS BEEN CARRIED TO LEVEL 6

5. DESCRIPTION OF TECHNOLOGY

The spectrometer assembly includes seven multispectral imaging channels using a pallet mounted high resolution scanner. The scanning section consists of scanning optics such as a rotating 45° mirror which collects the radiation from the scene measured and optics which focus the radiation through a field stop to the spectrometer or radiometer channels. Beyond the field stop, the light is collimated, passed through a dispersive element and focused on an array of detectors. The wavelength of each detector is determined by its position in the spectrum. Other equivalent methods may be used to separate the incoming radiation into each spectral channel.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. The desired field of view is driven by the need for high spatial resolution for earth resources and land use analyses. However, the designs of IR scanning spectrophotometers are restricted by the tradeoff between IR input signal sensitivity and spatial resolution versus dwell time on each spatial element.

b. The scanning spectroradiometer for the visible IR is used primarily in EO-06-S, Scanning Spectroradiometer but is also used as the thematic mapper in EO-08-A, Earth Observatory Satellite.

c. Better spatial and spectral resolutions enable better mapping and recognition of terrestrial features.

d. Due to uncertainity in effect of earth's atmosphere and weather on results obtained, a full size model operating in space with provable confidence levels is necessary. Probably a shuttle sortie flight can be utilized for testing in space.
Initial test can be performed in a high altitude aircraft to prove the technology.
The advancement is based on improving a lesser operational model, hence level 8.

TO BE CARRIED TO LEVEL 8

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DEFINITION OF TECHNOLOGY REQUIREMENT NO. C.2.12

1. TECHNOLOGY REQUIREMENT(TITLE): Scanning Spectroradiometer PAGE 2 OF 3
VIS-IR Instantaneous Field of View Reduction; Radiometric Accuracy

7. TECHNOLOGY OPTIONS: Spatial resolution is determined by the scan angle (through atmosphere), the optics quality, the detector size, and focal length. A scanning instantaneous field of view size of about 30 microradians is desired. Spectral resolution is determined by channel bandwidth and dispersive element quality. The spectrometer/radiometer channels may be calibrated by a number of alternative methods such as temperature controlled black bodies, cold sky background, integrating spheres, and radioisotopes. In order to obtain imaging in each of the spectral bands the small field of view ($\sim$ 30 μrad) is scanned across the flight path by a rotating mirror (fields up to 48° wide).

8. TECHNICAL PROBLEMS:

a. Dwell time of each detector upon each of earth surface spatial elements is small resulting in low signal levels which are susceptible to local noise.
b. Currently detector materials and cryogenic cooling techniques need improvement to improve signal to local system noise values.

9. POTENTIAL ALTERNATIVES:

Multiple IR electronic camera (or solid state imaging arrays) taking up to 7 frames (one in each desired spectral band) simultaneously in a slight overlapping series of frames might satisfy the requirements.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOPS: W74-70489 (177-22-81) Visible - Infrared Sensor System Technology Development, Richard R. Richard JSC, Ph 713-483-4661.
W740488, Visible and IR Sensor Subsystems, GSFC, Harvey Ostrow 301-982-4107.

EXPECTED UNPERTURBED LEVEL 6

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Development of sufficient scanning collector area.
b. Corrections for atmospheric effects versus altitude and angle from nadir.
c. Closed cycle cooling; combination of radiative and active cooling.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C. 2. 12

1. TECHNOLOGY REQUIREMENT (TITLE): Scanning Spectroradiometer PAGE 3 OF 3

VIS-IR Instantaneous Field of View Reduction; Radiometric Accuracy

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Options & Parametric Analy.	—																		
2. Design optics	—																		
3. Build Model	—																		
4. Test	—	—																	
APPLICATION																			
1. Design (Ph. C)		—	—																
2. Devl/Fab (Ph. D)			—	—	- -														
3. Operations						●	●	●	●	●	●●	●●	●	●●	●●	●●	●		

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	Total
TECHNOLOGY NEED DATE		T																
NUMBER OF LAUNCHES E1						1	1	1	1	2	2	2	1	1	1	2	2	26.
NUMBER OF LAUNCHES E2					1	1	1	1		1		1	1		1		1	

14. REFERENCES:

a. Summarized NASA Payload Descriptions, for Automated Payloads, Level A data, NASA PD, July 1974.
b. Summarized NASA Payload Descriptions, for Sortie Payloads, Level A data, NASA PD, July 1974.
c. Definition of the Technical Requirements for an Earth Resources Payload, Vol. 2, ESRO Contract SC/3/73/HQ, MBB, Munchen, 3 December 1973, pp. 114-117.
d. Comments, R. F. Hummer, Santa Barbara Research Center, 31 Dec. 1974.

Legend:

T = Technology
E1 = EO-06-S, Scanning Spectroradiometer
E2 = EO-08-A, Earth Observatory Satellite
● = Sortie Operations
⌐¬ = Automated Operations

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C.2.13

1. TECHNOLOGY REQUIREMENT (TITLE): Ocean Scanning Spectrophotometer PAGE 1 OF 3
I FOV Reduction, Radiometric Accuracy

2. TECHNOLOGY CATEGORY: Sensor

3. OBJECTIVE/ADVANCEMENT REQUIRED: Provide sensing with 0.37 to 0.6 milliradian instantaneous field of view scanned ± 45° with respect to orbital plane with a radiometric accuracy of 2% and a sensitivity of 3×10^{-5} J/m^2 (at 1695 km for E0-56-A, 250 km for OP-05-S.

4. CURRENT STATE OF ART: Current state of art is tending to approach the capability for electromechanical scanners but radiometric accuracy is only 5%. Up to twenty 15 nm bands from 400 to 700 nm have been recorded by the MOCS instrument in an AAF experiment over oceans and lake waters in 1972.

HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY

A 12 channel visible light, near infrared (IR) scanning radiometer (or spectrophotometer) is desired to provide global measurements of ocean color. The requirement can be met by a series of 12 linear arrays (each at a selected spectral band) or by operating 12 filtered imaging devices simultaneously. However, a number of problems exist requiring further advanced technology support.

Earlier experiments from an aircraft in 1972 used an image dissector tube to record the instantaneous image in twenty 15 nm bands from 400 to 700 nm. The spectra were scanned in sequency over a 150 point line on the tube. The principal application is the measurement of water color which is an indicator of subsurface phenomena such as plankton growth and pollution diffusion.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Gradations in water color per image indicate composition and subsurface phenomena such as plankton growth and polution diffusion.

b. The improved ocean scanning spectrophotometer is used in EO-56-A, Environmental Satellite but may be applicable to OP-05-S, Multispectral Scanning, ocean physics payload.

c. The multispectral ocean scanning spectrophotometer development will permit very accurate environmental coverage of ocean color with a spatial resolution up to a resolution of 1 km.

d. Test can be accomplished from a high altitude aircraft providing that equivalent to space observations conditions with respect to the scene can be achieved; a shuttle sortie flight test would be useful prior to deployment in an automated spacecraft.

TO BE CARRIED TO LEVEL 8

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DEFINITION OF TECHNOLOGY REQUIREMENT NO. C.2.13

1. TECHNOLOGY REQUIREMENT(TITLE): Ocean Scanning Spectrophotometer PAGE 2 OF 3
I FOV Reduction, Radiometric Accuracy

7. TECHNOLOGY OPTIONS: It is assumed that electromechanical scanners or static electronic imaging devices can scan the object or image plane in a manner that permits reconstruction of the scene radiance per spectral band. Besides the major options of an electromechanical scanner/radiometer or the array of static electronic filtered imaging devices, scanner parameters need to be traded. Key parameters are instantaneous field of view (angular resolution), radiometric accuracy, coverage rate, scanner size, number of channels, number and sensitivity of detectors, and various efficiency factors involved. Alternative scanners employing photomultipliers, photodiodes and photoconductors may be considered. The unique advantage that a tube system has over other types is the ability to accommodate a large number of spectral bands or a programmable, variable number of bands. In the tube system a prism or a grating is used to spread out a line of imagery (visible thru a slit) over the full raster of a tube.

8. TECHNICAL PROBLEMS:

a. As the I FOV is decreased, angular resolution increases, data rates are increased, calibration and vehicle stabilization requirements are tighter, need for cryogenics (to get greater detector sensitivity) increases. As the angular resolution is increased the dwell time of the detectors on a spatial resolution element may become less than detector time constant, resulting in decreased responsivity.
b. Resolution for a tube system with a limited readout rate is limited, since the bandwidth required is used for multiple copies of a single line.

9. POTENTIAL ALTERNATIVES:

a. Wide Range Image Spectrophotometer (Electron optics, image dissectors, vidicons).
b. Multispectral framing camera (with criss crossing patterns of striped filters).
c. Improved Multichannel Ocean Color Sensor (MOCS).

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP W74-70543 (177-55-41), Remote Sensing of Oceanographic Color, etc., W.A. Harris, GSFC Ph 301-982-6465.

RTOP W74-70546 (177-55-61), Physical Oceanography and Coastal Processes, including Marine Disasters, T. D. Oberholtzer (703-824-3411), Wallops Sta., Va.

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Forward motion compensation if frame cameras used.
b. Development of detector cooling systems if electromechanically scanned.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C.2.13

1. TECHNOLOGY REQUIREMENT (TITLE): Ocean Scanning Spectrophotometer PAGE 3 OF 3

FOV Reduction, Radiometric Accuracy

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Options & Parametric Analysis	—																		
2. Design Imaging Device	—																		
3. Build Model	—	—																	
4. Test Model		—	—																
APPLICATION																			
1. Design (Ph. C)			—	—															
2. Devl/Fab (Ph. D)				—	—														
3. Operations					T2 T1	●●	●●	●●	●●	●	●	●	●●	●●	●●	●	●		

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	Total
TECHNOLOGY NEED DATE			T															
NUMBER OF LAUNCHES T1						1	1	1			1	1	1	1		1	1	28
NUMBER OF LAUNCHES T2						2	2	2	2	1	1	1	2	2	2	1	1	

14. REFERENCES:

a. Summarized NASA Payload Descriptions, Automated Payloads, NASA PD, Automated Payloads, Level B Data, July 1974.

b. Pages 194, 291, NASA SP-335 Advanced Scanners & Imaging Systems for Earth Observations, Dec. 11-15, 1972.

Legend:

T = Technology

— = Automated Operations

● = Sortie Operations

T1 = EO-56-A, Environmental Satellite

T2 = OP-05-S, Multispectral Scanning

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.14-1

1. TECHNOLOGY REQUIREMENT (TITLE): IR Photometer PAGE 1 OF 3

Reduction in the number of instruments to cover 2 to 1000 μm range; Compatible with cryogenically cooled IR telescope. Flexibility in selection of any desired band 1 μm or larger in 2 to 1000 μm range.

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Photometric measurements at any selected band in 2 to 1000 μm range good to 0.1 magnitude

4. CURRENT STATE OF ART: Current state of art indicates measurement to 0.1 magnitude in 2 to 1000 μm requires 4 to 6 different IR instruments.

HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY

A single IR Photometer instrument is required to operate to 0.1 magnitude over the range from 2 to 1000 μm. This instrument must operate at 1.5°K and provide capability for switching in narrow band IR filters for radiation bands of interest which are mounted on a filter wheel. Different types of filters are necessary for different parts of the 2 to 1000 μm spectrum. An array of radiation detectors, each detector covering a part of the 2 to 1000 μm region, is required.

Probably IR photometer development will proceed in stages or cycles of about 4 to 7 years apart, contingent upon development of low loss bandpass filters.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Separate instruments covering parts of the 2 to 1000 μm region are available. Use of a collection of existing technology instruments is not feasible because of size restrictions for mounting in a liquid helium cooled environment.

b. This technology can benefit payloads AS-01-S, 1.5m Cryogenically Cooled IR Telescope, AS-20-S, 2.5m Cryogenically Cooled IR Telescope, and AS-11-A, 1.5m IR Telescope.

c. Use of a single instrument to cover the 2 to 1000 μm region will greatly reduce the number of flights or the time to accomplish the measurements associated with the payload.

d. When sufficient accuracy over the full range of IR radiation measurements has been demonstrated this technology requirement will have been met. Final test would be accomplished in space against standard spectral reference stars.

Initial test to prove technology can be performed on high altitude rocket flight.

TO BE CARRIED TO LEVEL 8

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DEFINITION OF TECHNOLOGY REQUIREMENT NO.C-2.14-1

1. TECHNOLOGY REQUIREMENT(TITLE): IR Photometer PAGE 2 OF 3

Reduction in the number of instruments to cover 2 to 1000 μm range; Compatible with cryogenically cooled IR telescope. Flexibility in selection of any desired band 1 μm or larger in 2 to 1000 μm range.

7. TECHNOLOGY OPTIONS:

Trade studies are associated with the type of narrow band IR radiation filters to use for different regions, the method of selecting specific narrow band filters, and the organization of multiple detector arrays. Calibration of the integrated instrument can be done using black bodies or in the operational environment using known stars as references.

Detector segmenting strategies should enable coupling of the detectors to the incoming point source IR signals as modified by the selected IR filter (i.e., proper detector area may be attained by connecting detector preamplifier outputs together.

8. TECHNICAL PROBLEMS:

a. The construction of selectable bandpass filters in the 2 to 1000 μm region.
b. Difficulty of calibrating all combinations of filters and detectors.
c. Operation in a low temperature environment (1.5°K).
d. Constancy of detector and calibration reference temperatures.
e. Development of stable detector elements in 30 μ to 1000 μm range.

9. POTENTIAL ALTERNATIVES:

a. Use of separate instruments to cover different parts of the IR region and limit experiment objectives for each mission.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. RTOP W74-70625 (188-41-55), Millimeter-Wave and Far-Infrared Astronomy, Goddard Inst. for Space Studies, Patrick Thaddeus, (212) 866-3618.
b. RTOP W74-70626 (188-41-55), Infrared Astronomy, NASA, Washington, D.C., N.W. Boggess, (202) 755-3688.
c. RTOP W74-70628 (188-41-55), Infrared Astronomy, Ames Research Center, Glen Goodwin, (415) 965-5065.
d. W74-70629 (188-41-55), Infrared Astronomy, Jet Propulsion Lab., Donald P. Burcham, (213) 354-3028.

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Low noise level detectors.
b. Segmented arrays of multiple detectors
c. Telescope that contributes minimum local flux.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.14-1

1. TECHNOLOGY REQUIREMENT (TITLE): IR Photometer PAGE 3 OF 3

Reduction in the number of instruments to cover 2 to 1000 μm range; Compatible with cryogenically cooled IR telescope. Flexibility in selection of any desired band 1 μm or larger in 2 to 1000 μm range.

12. TECHNOLOGY REQUIREMENTS SCHEDULE: CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Parametric Studies & Trades	T1, T3																		
2. Design & Fabrication of Exp. Model	T1	T3							T2										
3. Test & Evaluation		T1	T3							T2									
APPLICATION																			
1. Design (Ph. C)		T1	T3							T2									
2. Devl/Fab (Ph. D)			T1	T3							T2								
3. Operations					T1	• T3	••	••	••	••	•		•	• T2	••	••	••		

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE		T1	T3							T2								
NUMBER OF LAUNCHES						T1	2T1 T3	2T1	2T1	2T1 T3	T1		T1 T3	T1	T1 T2 T3	T1 T2	T1 T2	22

14. REFERENCES·

a. Summarized NASA Payload Descriptions, Sortie Payloads, July 1974, NASA/MSFC, pp. 30, 62.

b. Summarized NASA Payload Descriptions, Automated Payloads, July 1974, NASA/MSFC, p. 32.

c. Materials for Radiation Detection, National Materials Advisory Board, Jan. 1974, pp. 211-221, 333-343.

d. Astronomical Techniques, Volume II, edited by W. A. Hiltner, Chapter 7.

e. Payload Descriptions, Volume II, Sortie Payloads, Level B Data, p. 1-5, Sheet S-4A, Item AS-002, IR Filter Photometer, July 1974.

Legend

● = Sortie operations

— = Automated operations

(T1) = AS-01-S, 1.5m Cryogenically Cooled IR Telescope

(T2) = AS-20-S, 2.5m Cryogenically Cooled IR Telescope

(T3) = AS-11-A, 1.5m IR Telescope

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C.2.14-2

1. TECHNOLOGY REQUIREMENT (TITLE): IR Interferometer Spectrometer Resolving Power; Large Spectral Range in One Instrument PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: With one instrument, measure spectrum from 25 to 1000 μm with resolving power of 50000; spectrum may be measured in a number of overlapping sections.

4. CURRENT STATE OF ART: Current state of art indicates spectral range can be covered with a resolving power of 5000; higher resolution achievable by use of several instruments

HAS BEEN CARRIED TO LEVEL 6

5. DESCRIPTION OF TECHNOLOGY: An IR spectrometer/interferometer capable of covering the 25 to 1000 μm spectral range with a resolving power 50000 in one instrument is desired. The Fourier spectrometer technique depends upon stability of laser reference, precision of scan of reference arm, and dimensional stability. General principles: The optical configuration of a Fourier spectrometer includes a two beam interferometer with an easy (but accurate) way of varying the path difference (or delay) by moving some component. A detector gives the interference output, which consists of a uniform background signal upon which is superimposed an oscillatory function of the delay, called an interferogram. The current state of the art in the laboratory is in wave numbers between 0.1 and 0.05 decreasing to a value between 0.5 and 1 wave number at cryogenic temperatures. Two techniques are in use: rapid continuous, scan (L. Mertz) and step integrate system (P. Connes, et al).

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. The original requirement is for a single Fourier spectrometer assembly for use with an astronomical IR telescope over the total spectral range with best resolving power so that space is available on a given flight for other instruments. Then at the time the telescope is pointed at an IR source, a maximum of spectral coverage may be obtained with a few spectral range adjustments.

b. AS-01-S, 1.5 m cryogenically cooled IR Telescope, AS-15-S, 3 m ambient temperature IR Telescope, AS-20-S, 2.5 m cryogenically cooled IR Telescope, AS-07-A, 3 m ambient IR Telescope are IR telescope payloads which can benefit from development of a high resultion extended range IR spectrometer.

c. The availability of an extended range instrument of high precision will reduce the number of flights to obtain fairly complete spectra. The high resolution spectra enable source component identifications, line profiles, and velocities to be measured.

d. Final test of the desired spectrometer /interferometer will be accomplished in space coupled to a cryogenically cooled IR telescope on a shuttle sortie flight. Initial test would be performed in a cooled vacuum chamber.

TO BE CARRIED TO LEVEL 8

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DEFINITION OF TECHNOLOGY REQUIREMENT NO. C. 2. 14. 2

1. TECHNOLOGY REQUIREMENT(TITLE): IR Interferometer Spectrometer Resolving Power; Large Spectral Range in One Instrument

7. TECHNOLOGY OPTIONS: A simple interferometer observing an external point source of radiation passes the signal collected by a telescope through the interferometer to a point detector with low noise (local flux) background and a high dynamic range. The transit time for IR signal transfer for each ray path through the interferometer is Σ nd/c, the ray length d in each medium through which it passes divided by the speed of light in that medium. The difference in the delay time, for the two paths, delay J, is multiplied by the speed of light (IR) to give the path difference x = ct. The optical path difference is changed by increasing distance travelled in some part of one arm, usually by movement of a mirror. Most of the spectral range and resolving power problems involve the smoothness and precision of measurement of location of the mirror at any given time of the scan (so that the wavelength detected can be known accurately for each IR spectral element received). For the continuous drive method it is noted that observation efficiency is directly affected by

(continued on page 3)

8. TECHNICAL PROBLEMS:

a. To cover range, an equivalent 62.5 to 2500 cm retardation needed.
b. Operation of mechanisms in 1.5 to 2°K temperature range.
c. Large spectral coverage with one instrument 25 to 1000 μm (although instrument may be adjusted to scan complementary ranges during different observations).
d. Suppression of local flux, detector, photon, scintillation, and digitizing noise.
e. Dynamic range.
f. Detector size and coupling might be resolved by selectable area segmented detector array.

9. POTENTIAL ALTERNATIVES:

a. Step and integrate mode of operation.
b. Beam splitting of IR telescope output (with low loss); operation of two or three Fourier spectrometers to cover desired range.
c. Multiple mirror retardation (however, has reduced interferometer modulation).

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP W74-70629 (188-41-55) Infrared Astronomy,
N.W. Boggess, NASA Hq, Ph 202-755-3688.

EXPECTED UNPERTURBED LEVEL 6

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Electromechanical devices to enable precise scan or sampling.
b. Thermal control at lowest feasible temperature.
c. Development of 1 million Point Fast Fourier Transform Software and Computation Capability.
d. Increase of data handling capabilities by 10 to 20 times current rates.

1. TECHNOLOGY REQUIREMENT (TITLE): IR Interferometer Spectrometer; PAGE 3 OF 4
Resolving Power; Large Spectral Range in One Instrument

7. TECHNOLOGY OPTIONS (CONTINUED): fluctuations in mirror drive speed. In comparison of options, there are at least three distinct types of interest in astromony: Mach Zender with pairs of mirrors: Michelson with retroreflectors: and the cyclic. The Mach Zender interferometer has the advantage of separate outputs in which the interferogram data may be complementary. The complementary data may be useful in reducing noise from source fluctuations. The Michelson interferometer gives the simplest method of changing path difference and is the type most used in Fourier spectroscopy. In the Michelson interferometer the second output is returned to the source; it can be recovered if modified and mirrors have been replaced by retroreflectors.

Interferometer path variations can be described better in terms of the following parameters:

a. Shear, s (related to field images)
b. Shift, h (related to longitudinal separation)
c. Tilt t′ (related to source images)
d. Lead, 1′

In theory, there is no reason why a Fourier spectrometer should have either a shear or tilt. However, in practice they occur. The integrated effect of variations in path length is to reduce the modulation of the interferogram. Use of retroreflectors in future and coupling of these mirrors (back to back) in each arm will compensate for shear and tilt.

Choice of curvature of corner mirrors (or retroreflector characteristics) enables compensation for shifts and leads.

Areas which need further development are:

a. Truly background limited detectors for wavelengths longer than 100 μm.
b. Design techniques for high efficiency wide range coverage, capable of accepting beamsplitter and detector mixes to cover total desired spectral range exterior.
c. Improvement of retardation schemes, trades between multiple mirror and step and integrate concepts.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C.2.14.2

1. TECHNOLOGY REQUIREMENT (TITLE): IR Interferometer Spectrometer Resolving Power; Large Spectral Range in One Instrument PAGE 4 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Options & Parametric Analysis																			
2. Design Spectrometer																			
3. Fabricate Model																			
4. Test Spectral Range & Resolving Power																			
APPLICATION																			
1. Design (Phase C)																			
2. Devl/Fab (Phase D)																			
3. Operations					T1	• T5	••	•• T2 T4	•• ••	•• ••	• •	•	• •	• • T3	• • •	• • •	• • •		

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	Total
TECHNOLOGY NEED DATE		T																
NUMBER OF LAUNCHES S						1	2	2	4	4	2	1	2	2	3	3	3	
NUMBER OF LAUNCHES A							1		1	1		1	1		1	1		36

14. REFERENCES:

a. Aspen International Conference on Fourier Spectroscopy, 1970, AFCRL-71-0019, pgs 3-53.

b. Summarized NASA Payload Descriptions, Sortie Payloads, Level A Data, July 1974, NASA/MSFC, pp. 30, 56, 62.

c. Summarized NASA Payload Descriptions, Automated Payloads, Level A Data, July 1974, NASA/MSFC, pp. 30, 32.

d. Cryogenic Interferometer/Spectrometer, C. R. Bohne, L. B. Harkless & B. K. Yap, Honeywell Radiation Center, 11 Feb. 1974.

Legend:

T = Technology

• = Sortie Operations

—— = Automated Operations

T1 = AS-01-S, 1.5 m Cryogenically Cooled IR Telescope

T2 = AS-15-S, 3 m Ambient Temperature IR Telescope

T3 = AS-20-S, 2.5 m Cryogenically Cooled IR Telescope

T4 = AS-07-A, 3 m Ambient Temperature IR Telescope

T5 = AS-11-A, 1.5 m IR Telescope

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. RI,2.15

1. TECHNOLOGY REQUIREMENT (TITLE): IR Interferometer/Spectrometer — PAGE 1 OF 5

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: IR semiconductors and detectors (and associated electronics) which are less sensitive to high radiation backgrounds

4. CURRENT STATE OF ART: IR detectors are available which can withstand 10^7 rads with 50% degradation.

HAS BEEN CARRIED TO LEVEL *

5. DESCRIPTION OF TECHNOLOGY — *Some military classified activity

Semi-conductors demonstrate gain decreases and leakage current increases as a result of radiation. Required integration times also increase. These changes are attributed to traps which reduce charge carrier lifetimes and mobility. Minority carrier semi-conductors are especially vulnerable because the fraction of items which need to be affected to produce macroscopic effects is correspondingly less.

	Requirement	State of Art
Detector type	Thermal IR detectors, 0.7-100 μ	Thermal IR detectors 0.7-100 μ
Radiation level before damage	Jupiter environment at 4 Jupiter radii (>> 10^5 rad)	10^5 rads (without degradation) 10^7 rads (with 50% degradation)

(continued on page 4)

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. High radiation levels in Jupiter orbit have been analytically predicted and confirmed by Pioneer 11.
b. Using payload will be PL-12-A, Mariner Jupiter Orbiter.
c. Less radiation sensitive IR detectors are needed to operate the IR Interferometer/Spectrometer in Jupiter orbit.
d. Insensitivity to nuclear radiation with minimal shielding must be demonstrated in the laboratory.

TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. RI, 2.15

1. TECHNOLOGY REQUIREMENT(TITLE): IR Interferometer/Spectrometer — PAGE 2 OF 5

7. TECHNOLOGY OPTIONS:

If the designer will accept an allowable degradation in his detector response the detector will be able to withstand higher radiation levels over the required orbital time. An IR detector can withstand 10^5 rads at no degradation, 10^6 rads at 25% degradation, and 10^7 rads at 50% degradation. Table 1 illustrates allowable time in orbit as a function or detector degradation.

The present mission configuration requires orbiting Jupiter at 4 R_J (four Jupiter radii) for a period of one year. A design which allows detector degradation on the order of 50% is probably necessary. JPL has tested the effects of radiation on IR detectors and has found no damage at levels of 5×10^6 rads. (See Reference 5).

(Table 1 on page 4)

8. TECHNICAL PROBLEMS:

The associated electronics bias circuits signal amplifiers, ADC's, etc., must be balanced in hardness with the IR detectors or very little is gained. If two circuits are used, one open to and the other blind to IR energy, a subtraction logic may be used to define effects of radiation. However, in addition to resulting increased weights and power, the building of two circuits with identical radiation response would be difficult, and would require calibration over a very broad range to give any confidence to their use.

9. POTENTIAL ALTERNATIVES:

a. Shielding – Beyond shielding on the order of ~ 0.5 gm/cm^2, the effect of shielding weight on the orbiter is prohibitive. Table 2 illustrates shielding requirements as a function of orbit.

(continued on page 5)

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Work on hardening IR detectors against nuclear radiation is being carried out by:

Honeywell	R. A. Rotolante R. P. Murosako
Texas Instruments	M. M. Blanke S. R. Borrello

(continued on page 4)

EXPECTED UNPERTURBED LEVEL *_

11. RELATED TECHNOLOGY REQUIREMENTS:

* Some military classified activity

Unknown

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 2.15

1. TECHNOLOGY REQUIREMENT (TITLE): IR Interferometer/Spectrometer

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Materials Testing/ Research																			
2. Detector Development																			
3. Life Testing																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

NOTE: Technology required to meet Jupiter mission requirements is probably available at DoD, but classified. Availability of detector will negate need for development.

13. USAGE SCHEDULE:

																			TOTAL
TECHNOLOGY NEED DATE					▼														
NUMBER OF LAUNCHES							2												2

14. REFERENCES:

1. Discussions among N. Devine and J. C. Beckman, Jet Propulsion Laboratories, and Dr. J. Haffner, Rockwell International
2. A. G. Stansbery, and R. S. White, "Jupiters Radiation Belts", Journal of Geophysical Research, Vol. 79, No. 16, pp 2331-2342 (June 1974)
3. J. W. Haffner, "Calculated Dose Rates in Jupiters Van Allen Belt", AIAA Journal, Vol. 7, No. 12, pp 2305-2311 (December 1969)
4. Discussion between R. H. Parker, Jet Propulsion Laboratory, and P. R. Fagan, Rockwell International, January 20,, 1975
5. Thermoelectric Outer Planet Spacecraft, TOPS, Final Report, Jet Propulsion Laboratory, TM 33-589, April 1, 1973
6. Communication from D. J. Hamman, Batelle Columbus Laboratories to H. Ikerd, Convair, December 10, 1974

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RI, 2.15

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 4 OF 5

IR Interferometer/Spectrometer

5. Description of Technology – continued

Photoconductors can tolerate approximately 3×10^5 rads before appreciable damage. Photovoltaic detectors can tolerate approximately 10^5 rads before damage. Thermal detectors are two or more orders of magnitude less sensitive and can tolerate approximately 10^7 rads. Transient effects below these radiation levels manifest themselves as background noise. Transient effects are observed at one rad/hr in photoconductors and photovoltaic IR detectors.

7. Technology Options – continued

TABLE 1

NOTE: 0.1 gm/cm^2 shielding

Radiation Tolerance	Degradation	Orbiter Jupiter Radii	Allowable Exposure Time
10^5 rads	0%	4 R_J	4 orbits (~ 4 days)
10^6 rads	25%	4 R_J	40 orbits (~ 1 month)
10^7 rads	50%	4 R_J	400 orbits (one year)

10. Planned Programs or Unperturbed Technology Advancement – continued

Kaman Nuclear	P. L. Jessen
Gulf Radiation Tech.	B. C. Passenheim
	A. M. Kalma

Current research in the area of radiation effects on infrared devices is directed toward minimizing the transient response (which will increase the signal-to-noise ratio) as well as toward extending the exposure which can be tolerated before permanent damage become significant. Approaches being investigated include pulse-suppression electronic circuits (to minimize unwanted transient response), thermal grounding (to limit temperature rise due to radiation, especially laser radiation), and new material compositions which operate satisfactorily (high D*) with short minority carrier lifetimes). Various annealing techniques which can be used for certain applications are also under consideration.

Since nearly all of the research in this area pertains to classified applications, it is not possible to discuss recent results in an unclassified document (see the IRIS Conference reports for classified research reports).

9. Potential Alternatives - continued

TABLE 2

Shielding	Orbit	Radiation Level	Total Dose for 1-Year Orbits
0.1 gm/cm^2	4 R_J	10^4 rads/hr	10^8 rads
0.5 gm/cm^2*	4 R_J	4×10^3 rads/hr	4×10^7 rads
1 gm/cm^2*	4 R_J	7×10^2 rads/hr	7×10^6 rads
10 gm/cm^2*	4 R_J	3 rads/hr	3×10^4 rads

*Shielding at these levels results in prohibitive orbiter weights.

It can be seen that degradation higher than 50% (see Table 1) must be accepted with shielding on the order of 0.5 gm/cm^2.

b. Higher Orbits. Increased data collection time before failure can be accomplished with less detector degradation by selecting higher orbits. Table 3 illustrates the impact of higher orbits.

TABLE 3

NOTE: 0.1 gm/cm^2 shielding

Radiation Tolerance	Orbit	Allowable Exposure Time
10^5 rads	4 R_J	~ 4 orbits
	6 R_J	~11 orbits
	8 R_J	~37 orbits
10^6 rads (25% degradation)	4 R_J	~40 orbits
	6 R_J	~110 orbits
	8 R_J	~370 orbits (~ 1 year)

It can be seen that if an orbit at 8 R_J is acceptable, an orbit of approximately one year duration can be accomplished with a 25% detector degradation.

The time in orbit can be marginally increased by heavier shielding and substantially increased by using elliptical orbits with large apogees, preferably out of the plane of the magnetic equator.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.16

1. TECHNOLOGY REQUIREMENT (TITLE): Pyroelectric Detector PAGE 1 OF 4

Increase detectivity of uncooled detector to that of current cooled detectors

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop an IR detector with a detectivity of 3×10^{11}.

4. CURRENT STATE OF ART: Current state of art of triglycine sulfate pyroelectric detectors is approximately $D^* = 1 \times 10^{10}$ cm $HZ^{1/2} W^{-1}$

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

The pyroelectric detector employs a temperature-sensitive ferroelectric crystal, such as triglycine sulfate, which has two parallel electrodes deposited on it making it into a parallel plate capacitor. As the temperature of the polarized crystal is changed, a charge is generated in the pyroelectric detector. When employed in the voltage mode, the responsivity and the noise both decrease as a function of frequency and the D* of the detector stays nearly constant up to quite high frequencies. Pyroelectric detectors are particularly advantageous in wide bandwidth systems where their performance at both low and high frequencies is superior.

Pyroelectric detectors can be conveniently formed into linear arrays with associated preamplifier arrays for use in two-dimensional scanning systems. The current practical limit in the size of array elements is of the order of 0.25 x 0.25 mm. Below this area, for the current material and thickness limitations, the capacitance becomes small

(continued on page 3) P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Rationale for Selection: The improvement in detectivity in pyroelectric detectors obtained during the last five years has been about an order of magnitude. The best pyroelectric detectors being made in the United States and in England now approach a D* of 2×10^{10} cm $Hz^{1/2}$ W^{-1}, and the average detectors are within a factor of four of this value. The best detectors are now about a factor of ten away from the ideal thermal radiation noise limited performance. There appears to be no reason why considerable progress toward reaching this fundamental limit of thermal detector performance at about 20°C could not be made over the next few years. Recent studies of polyvinylfluoride film pyroelectric detectors are also of interest.

b. Benefitting payloads. Payload benefitting from development of improved IR detectors include:

(1)	OP-02-S	Multifrequency Land Imagery
	OP-03-S	Multifrequency Dual Polarized Microwave Radiometer
	OP-04-S	Microwave Scatterometer
	OP-05-S	Multispectral Scanning Imagery

(continued on page 3) TO BE CARRIED TO LEVEL 8

1. TECHNOLOGY REQUIREMENT(TITLE): Pyroelectric Detector

Increase detectivity of uncooled detector to that of current cooled detectors

7. TECHNOLOGY OPTIONS:

To the extent that the pyroelectric detector is an ideal capacitor, it is free of electrical noise and, therefore, would be limited only by temperature noise, which is the fluctuation of detector temperature through radiation exchange with its surrounding. In practice, at intermediate to higher frequencies the detector is generally limited by Johnson noise associated with the dielectric loss in the ferroelectric crystal. At low and very high frequencies, the limiting noise is usually that of the field-effect transistor preamplifier. Considerable progress has been made in improving the ferroelectric materials being used, in methods of attaching electrodes free of contact resistance, in minimizing electrical leakage around the detector, and in obtaining field-effect transistors with lower electrical noise characteristics. Noise equivalent power (NEP) for a pyroelectric detector is based on detector material, modulation frequency, FET characteristics and operating temperature.

(Continued on page 3)

8. TECHNICAL PROBLEMS:

a. Crystal growth needs to be perfected to obtain uniform crystals with minimum dielectric loss and methods of attaching leads need to be improved to avoid resistance loss in the lead attachment.

b. Preamplifier (FET's) needs to be reduced

c. Dielectric constant changes and responsivity goes down above some temperature such as 35° C. Pyroelectric detector needs to be generated within fairly narrow temperature band.

9. POTENTIAL ALTERNATIVES:

a. Cooled detectors

b. Electron beam imaging

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Some activity at Barnes Engineering, Mullard and Texas Instruments.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Low noise multispectral scanners.

b. Array element segmentation and coupling of elements for maximum efficiency vs wavelength.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.16

1. TECHNOLOGY REQUIREMENT (TITLE): Pyroelectric Detector PAGE 3 OF 4
Increase detectivity of uncooled detector to that of current cooled detectors

5. DESCRIPTION OF TECHNOLOGY (continued)
compared with the stray capacitance of the associated circuitry. For small elemental area detectors or arrays, materials of higher dielectric constant would be particularly valuable. Examples are SBN and PLZT.

6. RATIONALE AND ANALYSIS: (continued)

c. Justification for Advancement: It appears that considerable improvement in the characteristic of pyroelectric infrared detectors could be achieved with substantial research support. Because of the importance of pyroelectric detectors, not only as elemental detectors at low frequencies, but also as laser heterodyne receivers and in the pyroelectric vidicon, a strong and vigorous materials research program is recommended.

   Quite a few earth observations on geophysics payloads could avoid going to cooled detectors, if appropriate advance in pyroelectric detector occurs.

d. Substitution of typical pyroelectric detectors in a multispectral scanner test on an early shuttle flight. Initial test to be performed in high altitude aircraft.

7. TECHNOLOGY OPTIONS: (continued)

Ferroelectric materials should be investigated to find those having: (a) a better ratio of pyroelectric coefficient to dielectric constant, (b) greater thermal capacity per unit volume, and (c) higher Curie temperature. Material research is complicated by the wide variation of the dielectric properties of the material with temperature with the state of polarization of the crystal, with the previous thermal history, and with poling method employed. Several materials currently being investigated such as TGFB, deuterated TGS, alanine-doped TGS, SBN, and PLZT show considerable promise in this direction.

The responsivity of pyroelectric detectors above the thermal time constant is determined by the ratio of the pyroelectric coefficient to the dielectric constant of the detector material and the thermal capacity per unit volume of the detector material. To date this has been found to be optimum for triglycine sulfate just below its Curie point which occurs at 47°C and for triglycine fluoberyllate just below its Curie point of 73°C. A lower rather than a higher thermal capacity is advantageous for some type of pyroelectric detectors.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.16

1. TECHNOLOGY REQUIREMENT (TITLE): Pyroelectric Detector PAGE 4 OF 4

Increase detectivity of uncooled detector to that of current cooled detector.

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY:																			
1. Material Development																			
2. Detector Design & Fab.																			
3. Substitution in Multi-spectral scanner																			
4. Test in space																			
APPLICATION (in new sensor)																			
1. Design (Phase C)																			
2. Devel /Fab (Phase D)																			
3. Operations																			

13. USAGE SCHEDULE:

TECHNOLOGY NEED DATE			T															TOTAL
NUMBER OF LAUNCHES																		
OP-02-S						2	2	2	2	1	1	1	2	2	2	1	1	
OP-03-S						1		1		1	1	1	1		1	1	1	
OP-04-S							1		1	1	1	1		1		1	1	
OP-05-S						2	2	2	2	1	1	1	2	2	2	1	1	
						5	5	5	5	4	4	4	5	5	5	4	4	55

14. REFERENCES:

a. Materials for Radiation Detection, NMAB 287, January 1974.
b. Summarized NASA Payload Descriptions, Level A Data, Sortie Payloads, July 1974.

Legend:
T = Technology

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-2.17

1. TECHNOLOGY REQUIREMENT (TITLE): Soil Moisture Sensor

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Provide all-weather capability for mapping soil moisture from orbit.

4. CURRENT STATE OF ART: Microwave techniques currently under development ~~show good accuracy only under ideal soil conditions~~ relative to surface smoothness, freedom from vegetative cover, and known homogeneous soil compositions.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

a) Accuracy requirement - not attainable under operational measurement conditions (refer to item #4 above).
b) Resolution requirement - 100 meter minimum spot diameter from low orbit (up to 490 n.mi.); theoretically feasible with synthetic aperture radar techniques.
c) Soil depth of measurement - 0 to 50 cm; the higher limit does not appear to be feasible in the L-Band, which shows promise in terms of reducing the effects of vegetative cover.
d) If roughness and vegetation effects are to be eliminated, incidence angle range should not exceed 15^o.

Active microwave (radar) techniques show good response to soil moisture variations. The effect of roughness can be minimized if the system is operated over the 7^o-15^o incidence angle range at frequencies between 1 GHZ and 4 GHZ (experimental data ≈10% of full scale from dry to saturated soil). (Continued on page 3)

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a) Requirements are based on user needs in crop yield prediction, water supply forecasting, watershed modeling, flood area assessment, and snow run-off forecasting. Many of these applications could tolerate initial resolutions up to 4 KM diameter spot size.
b) The requirement to measure to a soil depth of 50 cm is particularly useful in crop yield surveys during seasonal measurements when the plant is obtaining water from the deep portion of the roots.
c) Technology advance is applicable to the following payloads: EO-08A, Earth Observatory Satellite, and EO-61A, Earth Resources Survey Operational Satellite. Both of these payloads will be active throughout the 1979-1991 period.
d) The development program required for this technology advancement should include fabrication of experimental models and testing in aircraft.

Ground truth sites will be required, as well as corroborating measurements of emissivity through IR scanners.

TO BE CARRIED TO LEVEL 6

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-2.17

1. TECHNOLOGY REQUIREMENT(TITLE): SOIL MOISTURE SENSOR PAGE 2 OF 4

7. TECHNOLOGY OPTIONS:

The choice of microwave techniques over optical sensing in the UV-VIS-IR spectral region is dictated by the requirements for all-weather capability, penetration of vegetation canopies, and moisture measurement below the soil surface. Within microwave techniques, the principal options are passive and active (radar). Although a passive system would be desirable for its simplicity of implementation, its resolution capability is limited to several kilometers spot size. The illumination frequency is an important parameter to be selected. L-Band looks promising. Multiple radar frequencies, with dual polarization is a possibility. The use of a combination of active and passive channels is a possible option. For instance, Dr. Fawwaz T. Ulaby, director of RemoteSensing Laboratory at the University of Kansas would propose the following:

(Continued on page 3)

8. TECHNICAL PROBLEMS:

The principal problems to be solved relate to the correlation of the microwave return signal with soil moisture content under a large spectrum of operational variables, including soil composition, soil structure, vegetation type/geometry/density, and observation incidence angle.

9. POTENTIAL ALTERNATIVES:

a) Should the stringent resolution limits that are required prove to be unfeasible, it may be necessary to rely on aircraft microwave measurements to this application. Space-based observations would be used merely for correlating.
b) Large number of in-situ moisture sensors could be installed in a network of ground instrumented platforms (e.g., one platform per 16 KM^2 with data relay link through satellite systems. (Continued on page 3)

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP #W74-70514, JSC, Joint Experiment on Remote Sensing of Soil Moisture, addresses the problem of proving feasibility of measurement by means of ground-based and air-based observations. RTOP-177-51-41 deals with microwave techniques for remote sensing. It is estimated that a 1980 flight target of this sensor on EOS will not be met unless a comprehensive sensor development program is continued during the interim period.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

The development of synthetic aperture radar imaging techniques will be directly applicable to this technology advancement. Investigations such as the Shuttle Imaging Microwave Sensor (EO-05S) may be significant in defining the degree to which advanced, passive microwave sensors will provide data for soil moisture surveys.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE2.17

1. TECHNOLOGY REQUIREMENT (TITLE): SOIL MOISTURE SENSOR

5. DESCRIPTION AND TECHNOLOGY (Continued)

generated under the RTOP #W74-70514, JSC, Joint Experiment on Remote Sensing of Soil Moisture). Also, for the same sensor parameters, radar signals can easily penetrate vegetation and measure a response due to soil moisture (1,2).

7. TECHNOLOGY OPTIONS: (Continued)

Radar	Radiometer
Frequency: 1-3 GHz range	Same as radar (with small offset to avoid interference
Incidence angle range: 7-15^{o} (lunar sounder synthetic aperture can be used)	Nadir
Polarization: Probably HH	Either (Nadir)

9. POTENTIAL ALTERNATIVES: (Continued)

The selection of the optimum number and location of ground sensors would require detailed surveys of soil types, soil structure, topography, and climatological conditions over the geographic areas of interest.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE 2.17

1. TECHNOLOGY REQUIREMENT (TITLE): SOIL MOISTURE SENSOR PAGE 4 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. ANALYSIS																			
2. DESIGN																			
3. FABRICATION																			
4. AIRBORNE TESTS																			
5. SHUTTLE SORTIE C/O																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE						Δ												
NUMBER OF LAUNCHES						1	1	1	1	1	1	1	1	1	1	1	1	12

14. REFERENCES:

1. "Radar Measurement of Soil Moisture Content", CRES Technical Report #177-35, by F. T. Ulaby (Contract NAS-9-10261).

2. "Geoscience Specifications for Orbital Imaging Radar", by J. W. Rouse, Jr. (Contract #NAS-1-11276).

3. "On the Feasibility of Remote Monitoring of Soil Moisture With Microwave Sensors", by Newton, Lee, Rouse and Paris. Paper by LMSC at 9th International Symposium on Remote Sensing of the Environment.

4. "Radar Response to Vegetation", Ulaby, F. T., IEEE Trans. on Antennas and Propagation, Vol. AP-23, No. 1, January 1975; also see CRES Technical Report 177-42, University of Kansas Center for Research, Inc., September 1973.

5. "Radiometer-Scatterometer Soil Moisture Detection", Eagleman, J., and F. T. Ulaby, Proceedings of the American Astronomical Society Meeting, August, 1974 Los Angeles, California.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-2.18

1. TECHNOLOGY REQUIREMENT (TITLE): Range and Range Rate Sensing PAGE 1 OF 5

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Range and range rate sensor suitable for automatic rendezvous/docking of the teleoperator to the disabled or serviceable spacecraft, and for gravimetric measurements in Earth and Ocean Physics.

4. CURRENT STATE OF ART: RRR sensor weighing less than 5 KG and capable of satisfying the teleoperator requirements does not exist, according to the report in reference #1. HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

(A) The teleoperator system requirements are to measure range to non-cooperative (disabled) targets from 3 KM to 1.5M, range rate from 6M/S to 1 cm/sec. Maximum system weight: 4.5 KG, maximum power 15 watts. The weight and volume constraints for this application are not considered within the state of the art.

(B) Earth and Ocean Physics application require measurements of range to 2 cm, and range rate to 0.003 cm/sec. The state of the art is approximately 20 cm range accuracy and 0.03 cm/sec.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a) The range requirement of 3 KM considers the possible deployment of the teleoperator assembly by the Shuttle or Tug at that distance away from the spacecraft to be serviced. Ground or TDRS-assisted tracking would be employed for longer ranges. Range rates down to near zero will be required during delicate close - in and docking maneuvers. Physical size and weight limitations are imposed by the overall teleoperator spacecraft weight and volume allocations.
b) Payload No. LS-04S, Free Flying Teleoperator, EOP will benefit specifically from this advancement. Other beneficiaries are the sub-satellites requiring deployment and retrieval from the Shuttle or Tug. The GRAVSAT system will benefit from this technology, in the Earth and Ocean Physics discipline.
c) Attainment of the desired advancement will increase the reliability and utility of the teleoperator system in a large variety of potential space applications. Precision range and range rate measurements are important in mapping the earth's gravity field for earthquake hazard assessment applications.
d) To be incorporated in the teleoperator design, the range and range rate sensor prototypes should be successfully demonstrated in ground tests.

TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GF-2.18

1. TECHNOLOGY REQUIREMENT(TITLE): Range and Range Rate Sensing PAGE 2 OF 5

7. TECHNOLOGY OPTIONS:

Laser or RF ranging techniques should be considered as options. Power consumption and pointing requirements may necessitate that a microwave system be used for coarse RRR sensing and laser be employed for fine sensing.

8. TECHNICAL PROBLEMS:

1. Implementation of a system to meet the stringent specifications within the weight and power constraints constitutes the technology problem.
2. Determination of accuracy limits imposed by ionospheric irregularities and tropospheric refraction on range and range rate measurements involving ground-to-space paths (Reference #3).
3. Specification of technique best suited for minimizing propagation errors in each application (See notes on the next page).

9. POTENTIAL ALTERNATIVES:

The use of three-dimensional television for close-in maneuvers was considered in early teleoperator concepts (see reference 2).

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Related programs: RTOP No. 970-63-20, Teleoperator Control & Manipulation; RTOP No. 502-33-95, Video Guidance, Landing and Imaging System for Space Programs

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

None identified.

8. TECHNICAL PROBLEMS (Continued)

NOTES: Dr. Roy E. Anderson (GE, Corporate Research and Development Laboratory) discusses the ionospheric and tropospheric problem and some of the work that has been performed to date:

"We have investigated the effects of the ionosphere and troposphere on the accuracy of range and range rate measurements of missiles and spacecraft.

"A radio signal is delayed as it passes through the ionosphere. At VHF frequencies, the delay may be equivalent to 2000 meters range error at midday. The effect varies as $1/F^2$, hence it is much smaller at higher frequencies. One way to correct for it is to employ two coherently related, widely separated frequencies, measure the difference in their phase at the receiver, and apply a range or range rate correction according to the $1/F^2$ relationship. The method has been applied very successfully in the Navy Transit satellite navigation system. Another, less accurate approach is to apply corrections based on ionosphere models.

"The ionosphere usually contains irregularities in electron density resulting in horizontal gradients that cannot be individually described by a model. The two-frequency method is one way to measure the irregularities.

"We have calculated the effect on missile velocity measurements of the horizontal gradients of electron density and find that at L-band, 1500-1600 MHz the apparent rate of change of range due to changing electron content along the ray path can far exceed the specifications stated in GE-2.18.

"We have also considered the effect of tropospheric refraction on the measurement of range rate. Tropospheric refraction causes a bending of the ray path from an object above the earth to a measuring device near the earth's surface. The effect is independent of frequency. An error in the measurement of range rate results when the object is at a low elevation angle and moving with a high velocity component toward or away from the measuring device. Bending of the ray path results in a slight error in the viewing angle at the fast moving object. Observed doppler frequency shift, hence velocity, is a function of the viewing angle. The cause of the error is described more completely in "A Survey of Tropospheric, Ionospheric, and Extra Terrestrial Effects on Radio Propagation Between Earth and Space Vehicles" by G. H. Millman, GE Report TIS R66EMH1, presented at NATA-AGARD Symposium on "Propagation Factors in Space Communications", Rome, Italy, Sept. 21-25, 1965. The report also contains data for calculating the magnitude of the effect. As an example, the troposphere will cause a velocity measurement error as large as ten feet per second for a missile at 30 KM altitude traveling 20,000 feet/second, viewed at an elevation angle of 10°. The error may be corrected to within 5 or 10% of the total error by the measurement of atmospheric temperature, pressure, and humidity at the receiving site.

(Continued)

8. TECHNICAL PROBLEMS (Continued)

"Our studies and experiments to date suggest that the propagation effects must be considered in any application requiring high accuracy in range and range rate measurements. The relatively small amount of data from our own work and from other sources points up the problem, but much more data are needed before the magnitude of the problem can be defined precisely and applied to specific applications.

DEFINITION OF TECHNOLOGY REQUIREMENT　　　　NO. GE-2.18

1. TECHNOLOGY REQUIREMENT (TITLE): Range and Range Rate Sensing　　　　PAGE 5 OF 5

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Lab Investigation	—																		
2. Prot. type Design		—	—																
3. Prototype Fabrication			—	—															
4. Ground Tests				—	—														
5. Space Demonstration					—	—													
APPLICATION																			
1. Design (Ph. C)					—	—													
2. Devl/Fab (Ph. D)						—	—												
3. Operations							—	—	—	—	—	—	—	—	—	—	—		
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE						Δ												
NUMBER OF LAUNCHES							1	2	1	1	1	1	1	1	1	1	1	12

14. REFERENCES:

(1) Shuttle Free-Flying Teleoperator System Experiment Definition, Contract NAS-8-27895, Report #D7425-953004; and Contract NAS-8-29153, Report #D7425-953008 (Bell Aerospace Co.)

(2) Application of Remote Manipulation to Satellite Maintenance, Contract NAS-2-5072.

(3) "Ionospheric Phase Fluctuations of Satellite Transmissions", By George H. Millman and Ray Anderson (General Electric Company), Journal of Geophysical Research, Volume 73, Number 13.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.19

1. TECHNOLOGY REQUIREMENT (TITLE): High Resolution Photon Counting Detector PAGE 1 OF 14

Improve high resolution angular coverage; improve resolution; improve dynamic range.

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Obtain 0.03 arc sec resolution over a 300 to 375 arc sec field with a photon counting dynamic range $>10^7$. (Desired image area 200 to 500 mm dia.). At least 20000 × 20000 picture elements will be needed to obtain 0.03 arc sec resolution.

4. CURRENT STATE OF ART: A SEC-Orthicon of 75 mm dia. with a read area of 50 x 50 mm and a resolution of 33 lines/mm at 80% MTF is currently being developed.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

For large visible light/UV telescopes, there is need for a larger area detector capable of 0.03 arc seconds resolution over a 300 arc second field when operating in a photon counting mode. To enable more complete imaging of astronomical objects in a 300 arc sec region, a dynamic range $>10^7$ is desired. The large high resolution photon counting detector enables observers to obtain a maximum of the high resolution angular coverage available from large telescopes such as the LST. The increased coverage of the detector improves observation efficiency for detailed surveys per unit time by a factor of 100. It is predicted that read areas up to 500 x 500 mm, capable of 50 lines per mm at 80% MTF may be possible. Previous or current technology development objectives were to obtain a 50 x 50 mm read area with a capability of 33 to 40 lines/mm at 80% MTF.

Noiseless gain or electron multiplication (intensification) in parallel format is desired after the initial conversion from incoming photons to electrons.

(Cont'd on Page 2)

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. High resolution coverage of a large visible light and UV telescope operating in space from an automated satellite is currently limited by the detector angular (and area) coverage. The optical systems can provide up to 100 times the high resolution image plane area or field that our best high resolution electronic imaging devices can use.

b. The follow-on or later flights of payloads such as AS-01-A, Large Space Telescope; AS-14-A, 1 m UV Telescope; AS-04-S, 1 m Diffraction Limited UV Optical Telescope, as well as AS-03-S, Deep Sky UV Survey Telescope, can benefit from development of large angular field, large area detectors.

c. The development of high resolution, large area detectors with read areas between 200 x 200 mm and 500 x 500 mm will enable better utilization of observation opportunities and produce from 10 to 100 times more information per observation.

d. Satisfactory development of the photon counting detector will be complete when a 300 arc sec field has been imaged in space to a 0.03 arc second resolution. An earlier feasibility milestone will include building a smaller 200 x 200 or 1000 x 1000 pixel photon counting device expandable to the larger one.

A full scale version will be tested in space, e.g,. shuttle flight.

TO BE CARRIED TO LEVEL 7

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1. TECHNOLOGY REQUIREMENT (TITLE): High Resolution Photon Counting Detector

Improve high resolution angular coverage; improve resolution; improve dynamic range.

5. DESCRIPTION OF TECHNOLOGY (cont'd)

Since it may be difficult to obtain one photon counting detector to cover IR (5 μm to 0.7 μm) visible light (0.7 μm to 0.4 μm), and UV (0.4 μm to 0.09 μm) in one instrument, several instrument types may be necessary.

7. TECHNOLOGY OPTIONS

Low f-number optical systems can achieve 100 times greater limiting MTF than many typical sensors but are only a few times better than the highest resolution sensors such as the RCA Return Beam Vidicon. On the other hand, high sensitivity sensors such as the Orthicon, Isocon and EBS/SIT can trade f-number for diffraction limit until they exceed the information gathering capability of film if the optical system is optimized for electro-optical systems. An increase in sensor capability to 5000 × 5000 elements would be more than sufficient to achieve the increased field-of-view desired for a few purposes; however, the desired angular coverage would not be achieved. When one looks in a given direction with a long time exposure, all the details in the whole fine resolution field ought to be obtained in order to maximize observing efficiency.

(cont'd on page 3)

7. TECHNOLOGY OPTIONS: (cont'd)

Practical detector devices for the 0.1 to 2.0 μm spectral range can be organized into three classes: (a) photon to electron converter + electron multipliers such as microchannel plate photomultipliers and image intensifiers; (b) solid state devices such as photoconductors, photodiodes, and photo-transistors, IC CCD's, and (c) hybrid storage + amplifier devices such as electronic camera tubes including SEC vidicons, SIT vidicon, SEC-orthicons. Most practical devices are hybrid. Solid state devices may be used in arrays coupled to image intensifiers. Overlapping selected bands in the 2 μm to 0.1 μm spectral range are covered in discussion of options for imaging detectors, which follows:

These devices are considered in more detail below. The key detector element in vacuum devices is the photocathode where incoming radiation is converted into electrons which are emitted into vacuum for subsequent processing. It is the photocathode therefore, which has received emphasis in the discussion of vacuum devices rather than the devices themselves.

Quantum counters have been examined for many detector applications, including imaging, but are relatively inefficient and have an optical detection bandwidth too narrow for most applications. However, recent experiments indicate that investigation into these naturally band limited devices may need to be resumed. (Some work on stimulated emission infrared sensors has been accomplished by Varian.)

Several important advances have been made in recent years in materials and device technology for detectors in this spectral range. Examples are the introduction of the negative electron affinity photocathode, the development of the silicon diode array vidicon, and the low-noise, high-gain silicon avalanche photodiodes, and the demonstration of surface charge-coupled imaging arrays. These developments have led to an increasing degree of commonality in the materials technology applicable to both vacuum and solid state devices. For example, negative electron affinity photocathodes with gallium arsenide sensing layers can be described by the same diffusion model for carrier transport as would be gallium arsenide p-n junction photodiodes. This is in contrast to conventional multialkali antimonide photocathodes whose operation has largely defied all but the crudest analytical treatment. This has been an important factor in the developing materials technology of the new photocathodes. The rapid development of planar integrated circuit technology has affected the size and quality of pre-amplifier and amplifier packages for detector elements and television cameras and of power supplies for image intensifiers and detectors alike and is responsible for the fabrication technology for silicon diode array vidicon targets. Finally, the surface charge-coupled devices offer a highly flexible technique for self-scanned, imaging detector arrays with the possibilities of low-noise operation and integrated signal processing.

(Continued on Page 4)

Improve resolution over 300 arc sec FOV: improve dynamic range

7. TECHNOLOGY OPTIONS: (Cont'd)

Considerable emphasis has been placed here on basic photodiode detection processes without a discussion of classical photoconductors. To a large extent, this is a reflection of the growing importance of photodiodes in detector systems for this spectral range. The photoconductor is a slab of extrinsic (doped) material with ohmic contacts at both ends. Signal generation occurs when incident light reduces the dark resistance of the material, allowing increased current to flow when bias is applied. These devices frequently can be made to exhibit gain due to minority-carrier trapping at controlled defect sites. When this occurs, excess majority carrier current will flow until the trapped minority carriers are neutralized. For the most part, II-VI compounds such as ZnS, SnSe, CDS, CdSe, and CdTe have been used as photoconductive detectors. Control of the doping level, trap type, and distribution is critical if reproducible results are to be obtained.

The gain mechanism itself provides a limitation on useful performance. Since the gain is achieved by a trapping process, changes in input light level will not be manifested until trapped carriers are ejected and swept out or neutralized. High gain, however, requires long trapping lifetimes so that these devices tend to have slow response times. This is particularly acute at low light levels. The dark current in photoconductors is predominantly due to majority carriers. Since this current sets the low-level threshold for detection, suppression of dark current can be achieved by reduction of the doping level or cooling, both of which reduce the number of majority carriers available for recombination with trapped minority carriers which increases trapping lifetimes. In reality, the behavior of trapping lifetime with temperature or doping level may be considerably more complicated, depending on the energy level of the trap in the forbidden band and the capture cross sections for both types of carrier. In general, however, speed of response becomes an increasing problem as detection threshold is reduced.

Noiseless gain has been achieved in special forms of electronographic cameras, however, an electronographic camera does not lend itself to computer compatible readout from an automated satellite in orbit. Therefore part of the research problem for the high resolution photon counting detector is to provide appropriate digital accumulation and readout of the resultant frame for each stabilized observation period.

One of the options proposed by Fred Schaff of Westinghouse suggests the following approach.

a) Achieve the current diode density of 4×10^6 diodes per square inch used with SIT/EBS sensors in a back illuminated, thinned CCD or CID.

b) Design the above device to either 25 or 50 millimeter squared chips with registers, amplifiers, etc., masked on the back of the chip to allow edge butting on all four sides

c) Assemble 100 25-millimeter square or 25 50-millimeter square chips on a stiffened auxiliary surface.

(continued on page 5)

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 2.19

1. TECHNOLOGY REQUIREMENT (TITLE): High Resolution Photon Counting Detector PAGE 5 OF 14

7. TECHNOLOGY OPTIONS: (Cont'd)

d) Use Item (c) in direct photon-in mode for 20,000 x 20,000 array with silicon spectral capability.

e) Process in space a 500 x 500 millimeter photocathode on the desired surface and mount in a proximity focused mode on the array of Item C, and operate unenclosed relying on the space vacuum. This retains the 20,000 x 20,000 element resolution but adds essentially noise free gain of 3000 to 5000 with a variety of spectral responses as a function of the photocathode/faceplate combination.

f) True photon counting requires sufficient gain to allow a single photon event to stand out above all noise sources. Since most noise sources are a function of bandwidth and, in turn, bandwidth is dependent on frame time and number of resolution elements, an exact value of required gain cannot be specified but is generally above 10^5 for a reasonable system. This would then require additional stages in addition to the detector of Item (e) which could be achieved in a single stage with micro channel plate intensifiers if channel size can be reduced to the 12 micron or smaller size of the diode array.

g) The combination of dynamic range of $>10^7$ and 20,000 x 20,000 picture elements requires 4×10^8 words at 24 bits per word, or 9.6×10^9 total storage which, in itself, represents an improvement in the state-of-the-art for memory systems in space. Using the sensor as a photon-counter requires only 2 bits per picture element per frame, but the rate of photon arrivals for all but the dimmest objects requires frame times in the order of fractions of seconds to perhaps 10 seconds. This would require real time computations on the order of 80 megabits per second at the 10 second frame time or higher.

8. TECHNICAL PROBLEMS:

a. Suppression of spurious photon counts, background or thermal noise
b. Deviation of focused surface from ideal flat image plane.
c. Quantum efficiency versus selected spectral bands.
d. Methods for data readout in reasonable time, preferable less than exposure time per sampled frame
e. Metric and photometric stability.
f. Current devices have a poor dynamic range.
g. Necessity for processing immediately at the detector.
h. Need for noiseless gain.

A more detailed discussion of some possible technical problems follows:

Avalanche multiplication often degrades the frequency response of a photodiode due to the feedback effect of the multiplication process. If both electrons and holes cause ionization, the duration of a current pulse will increase with multiplication. In general, a distribution of ionization lengths and times exists, and the pulse will cut off only when all carriers are finally swept from the field region. The pulse has, in the meantime, increased in length.

Alternatively $[F(\omega, \alpha)]^2$ has been degraded and becomes $[F(\omega, \alpha, M)]^2$, a decreasing function of the avalanche gain, M. If the electron and hole ionization rates is somewhat different. The frequency response of the diode will degrade by a factor of two at most but a large increase in detector gain bandwidth product is possible. This is only true if

(continued on page 7)

8. TECHNICAL PROBLEMS (Cont'd)

the carrier with the largest ionization rate initiates the avalanche. The frequency dependence of the avalanche gain itself is absorbed into a factor $[M(\omega)]^2$ multiplying $[F(\omega, \alpha, M)]^2$. In principle, the signal-to-noise ratio is substantially independent of gain when the ionization coefficients are grossly disparate. (α = absorption coefficient)

The underlying assumption regarding photodetectors with more than one noise source present is that no correlation exists between the noise sources, so that their respective noise "currents" may be added in quadrature. The four noise sources considered here are Johnson (thermal) noise, shot noise, i_f noise, and avalanche multiplication noise. Bulk generation-recombination noise is frequently found in photoconductors and is generally equal in magnitude to the shot noise but does not contribute in junction devices. While all noise sources have a frequency dependence, particularly at high frequencies, the low-frequency case ($\omega < 1/\tau$) will be assumed here for simplicity. (The following noise discussions are repeated here for convenience only; they are credited to NMAB287, Materials for Radiation Detection, Jan. 1974, National Academy of Sciences/National Academy of Engineering.

Johnson Noise - Solid-state detectors, photomultipliers, and vidicon camera tubes generally have associated with them a load resistor across which a signal voltage is developed by the device output current. While not part of the detector itself, the load resistor is frequently a limitation on the performance of the detector package. Further, in some detectors, series resistance in the detector itself may influence device performance. In both cases, random thermal motion of carriers through the material gives rise to fluctuations in the current. The mean square noise current is then given by:

$$\left(\overline{i_{JN}^2}\right) = \frac{4kT\ \Delta f}{R}, \qquad \text{Equation 5.5}$$

where k is Boltzmann's constant, T is the absolute temperature, Δf is the measurement bandwidth, and R is the value of the load or series resistance. (JN = Johnson noise)

Morton has pointed out that a deliberate or parasitic capacitance, C, in a photodiode circuit may limit its performance as a photon counter. In conjunction with the diode load resistance, R, the bandwidth $\Delta f = 1/RC$ or $R = 1/C\Delta f$. In these terms, Equation (5.5) becomes:

$$\left(\overline{i_{JN}^2}\right) = 4e\left(\frac{kT}{e}C\right)\Delta f^2, \qquad \text{Equation 5.6}$$

(continued on page 8)

8. TECHNICAL PROBLEMS: (cont'd)

Shot noise - In solids it is possible for the density of carriers to fluctuate about the steady-state value. Such fluctuations occur in the emission of electrons by a cathode or the arrival of photons at the surface of the detector. In all cases, the mean square shot noise current associated with a current, I, is given by:

$$\overline{\left(i_{SN}^2\right)} = 2eI\Delta f\,, \qquad \text{(SN = shot noise)} \qquad \text{Equation 5.7}$$

where e is the electron charge. The current, I, includes both signal and dark current.

Photons at a specific wavelength, λ, with the flux ϕ_o photons/cm^2-sec, are converted into signal electrons with the efficiency $\eta(\lambda)$. Consequently, fluctuations in ϕ_o will be reproduced in the signal current but will correspond to the reduced arrival rate $\eta\phi_o$. The signal current used in Equation 5.6 for a detector of area A is then:

$$I = e\eta\phi_o A\,, \qquad \text{Equation 5.8}$$

Dark current in semiconductor diodes (including photocathodes) arises from either thermal generation across the gap or through impurity centers (traps) with energies located within the forbidden band. In p-n junctions, the generation-recombination process takes place primarily within the junction depletion region. The current due to bandgap generation outside the depletion region is given by:

$$I = e\left(\frac{D_n}{\tau_n}\right)^{\frac{1}{2}} \frac{n_i^2}{N_A}\, A, \qquad \text{Equation 5.9}$$

where contributions from the n-type side of the junction have been suppressed and the diode is assumed to be heavily reverse biased. D_n and τ_n are the diffusion constant and lifetime respectively of electrons in the p-type region, n_i the intrinsic carrier density, and N_A the acceptor doping density. The trap generation current, I_g, is found from the expression:

$$I_g = e\frac{n_i W}{\tau_e} A\,, \qquad \text{Equation 5.10}$$

where W is the width of the depletion region. τ_e is the effective electron lifetime due to traps in the depletion layer and varies inversely with trap density.

It is important to note that generation-recombination current increases with the width of the depletion region and the inclusion of more trapping centers. Since the carrier densities are suppressed due to sweep-out by the field, only the generation process is significant with the trap alernately emitting electrons and holes as indicated above.

The shot noise current contributed by these processes is then given by:

$$\overline{\left(i_{SN}^2\right)} = 2e^2 A\left[\eta\Phi + \left(\frac{D_n}{\tau_n}\right)^{\frac{1}{2}} \frac{n_i^2}{N_A} + \frac{n_i W}{\tau_e}\right]\Delta f. \qquad \text{Equation 5.11}$$

(continued on page 9)

8. TECHNICAL PROBLEMS: (cont'd)

i_f Noise - The surface of the detector material, particularly near a junction may contribute a separate noise current, one source of which is generation-recombination events due to surface states. The noise current can be represented by:

$$\langle \overline{i_f^2} \rangle = \frac{BI^2 \Delta f}{f}, \qquad \text{Equation 5.12}$$

where B is an empirical constant. Suppression of this source of noise is critically dependent on the passivation of the detector surfaces and consequently is strongly related to the materials technology available for a particular material.

Avalanche Multiplication Noise - Current amplification by avalanche multiplication is an internal secondary "emission" process and as such is subject to fluctuations in the mean carrier gain per incident carrier, the multiplication factor M. This process then gives rise to an additional noise current

$$\langle \overline{i_{JN}^2} \rangle = 2eIM^3 \Delta f. \qquad \text{Equation 5.13}$$

When electron and hole ionization rates are related, $\alpha_p = k\alpha_n$, McIntyre has shown that

$$\langle \overline{i_n^2} \rangle = 2eIM^3 \left[1 - (1-k)\left(\frac{M-1}{M}\right)^2 \right] \Delta f, \qquad \text{Equation 5.14}$$

for injected electron current.

A special case of the diode noise treatment is the negative affinity photocathode, which should exhibit no avalanche noise since the fields are insufficient to support avalanche multiplication. It is doubtful if either thermal noise or 1/f noise would be present in the photoemission. Consequently, the noise current from this device will be the sum of contributions given in Equation (5.12) from the photon flux and carrier generation in the bulk and the surface band-bending (depletion) region. The relative contributions to dark current and total noise currents in negative affinity photocathodes were treated by Bell, who concluded that generation currents from the band-bending region and surface states would dominate the dark current.

As in the case of detectors in the far infrared, a figure of merit can be defined for these detectors. The ideal detector is limited in performance only by shot noise in the incoming photon signal. The signal-to-noise ratio can them be written as:

$$\frac{S}{N} = \frac{I_s^2}{2eI_s \Delta f} = \frac{\eta \Phi_o A}{2\Delta f} = \frac{\eta P_o A}{2h\nu\Delta f},$$

where Equations (5.7) and (5.8) have been used and $P_o = h\nu\Phi_o$ is the input power density with photon energy $h\nu$. The threshold power P_T is defined for S/N = 1 as:

(continued on page 10)

8. TECHNICAL PROBLEMS: (cont'd)

$$P_T = \frac{2h\nu}{\eta A} \Delta f \text{ (watts/cm}^2\text{)},$$

from which the noise equivalent power (NEP) is given by:

$$NEP = \frac{P_T A}{(\Delta f)^{\frac{1}{2}}} = \frac{2h\nu}{\eta} (\Delta f)^{\frac{1}{2}} \text{ (watts/Hz}^{\frac{1}{2}}\text{)},$$

and the limiting detectivity D^*_L becomes

$$D^*_L = \frac{A^{\frac{1}{2}}}{NEP} = \frac{\eta}{2h\nu} \left(\frac{A}{\Delta f}\right)^{\frac{1}{2}} \text{(cm-Hz}^{\frac{1}{2}}\text{/watt)}.$$

η = quantum efficiency, electrons emitted per incident photon.

For example, at 1eV($\approx 1.2\ \mu m$), a detector with 100 percent quantum efficiency and an area of 1 cm^2 feeding a 1 Hz bandwidth has a $D^*_L = 3 \times 10^{18}$ cm-$Hz^{\frac{1}{2}}$/watt. Real detector efficiencies will be less than 100 percent due to reflection, absorption, and transport losses and will result in reduction in the measurable D^* even if other noise sources can be neglected. At wavelengths beyond 1.2 μm, the blackbody background becomes the limiting factor with a resultant decrease in D^*_L. Also as $\nu \to \infty$, $D^*_L \to 0$ as is apparent from the above definition.

The reader is advised that D^*_L defined here differs from that used in the infrared in that it is not independent of area and bandwidth.

Real detectors seldom have efficiencies approaching unity unless gain is present in the detector itself (photoconductors or avalanche diodes). A detector with 10 percent intrinsic efficiency (without gain) can have unity efficiency at its terminals if gain is present. However, in many applications (imaging, photon counting) such a detector has irretrievably lost 90 percent of the available information. For this type of detector, high quantum efficiency is imperative regardless of the current gain available or its location in the system.

The material parameters limiting detector performance can easily be identified. The reflection and absorption coefficients are functions of the band structure, temperature, and, near the absorption edge, the impurity density. The reflection from the input surface can be minimized by an antireflection coating.

The parameters τ and μ in most semiconductors of practical interest are adversely affected by the defect density in the materials. The mobility is reduced by increasing scattering from dislocations, grain boundaries, vacancies, and impurity centers as material quality is reduced. These same defects result in shorter carrier lifetimes by acting as recombination centers when they appear in the bulk of the material and as dark current generators when in a depletion layer.

(continued on page 11)

8. TECHNICAL PROBLEMS: (cont'd)

The effect of surfaces is similar. Surface states arise in part, due to a discontinuity in the material resulting in local surface strain and accompanying defect states. Growth of a detector material onto a substrate has a similar effect if the mechanical properties (lattice parameters and thermal coefficients of expansion) do not properly match. Extra states can be added, due to interaction with the environment, by adsorption of or chemical reaction with foreign atoms. Controlled treatment of surfaces with foreign substances (passivation) can reduce or compensate surface states. The surface can act as a sink for both minority and majority carriers and as a source of extraneous noise. In addition to pure chemical or material treatment, it is possible in junction devices to provide an encircling junction or contact that is independently biased to prevent surface leakage from reaching the output junction. Similarly, if a passivation material is used, it is possible to deposit an encircling electrode on the passivator to further suppress leakage with the passivator. Surface breakdown of avalanche diodes has been suppressed by diffusing an encircling junction (guard ring) contiguous with the detector junction but at a lower doping density so that surface fields are always much lower than in the bulk.

Dark current is a potentially major limitation for low-input-power levels and narrow-bandgap detectors if the output of the detector must be directly coupled to the amplifier or readout device. In this case, the operating temperature of the detector is reduced until an adequate ratio of signal to noise is obtained at the lowest input-power levels likely to be encountered, or other limitations are encountered. In depletion layer devices such as fast photodiodes or avalanche photodiodes, the dark current decreases as $kT/2$ due to the trap generation process and increases linearly with depletion layer width and the trap density. This implies that the temperature will have less effect on dark current than in the case of bulk generation, so that reduction of trap density is necessary to provide low dark currents. A simple numerical example will illustrate the magnitude of the difficulty involved. In a silicon diode at room temperature 10^{12} traps/cm^3 with energies at midgap will result in a dark current density of approximately 10 nanoamps/cm^2 for a depletion layer width of 10 μm. Lower trap densities than this strongly push the state of the art in the materials.

Note: (As noted before the noise problem is stressed in order to provoke development of concepts with a high probability of minimizing spurious responses and noise. The reader is invited to modify, delete, and replace portions of the preceding discussion in order to clarify the technology problem).

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 2.19

1. TECHNOLOGY REQUIREMENT (TITLE): High Resolution Photon Counting Detector PAGE 12 OF 14

Improve resolution over 300 arc sec FOV; improve dynamic range

9. POTENTIAL ALTERNATIVES:

a. Electromagnetically focused image intensifier such as being developed for AS-03-S, AS-13-A. Deep Sky UV Survey Telescope. (Wide field electronographic camera).

b. An array of electronic cameras, segmenting or splitting high resolution field into zones. (However, tends to have different response per camera, making small differences difficult to detect.)

c. Bimat film with densitometer readout; combination of film images in densitometer output form on the ground.

d. Electrostatic camera tubes.

e. To achieve the gain required for photon counting, electron gain is required in the sensor. To achieve this and maintain the resolution requires either channel plate multipliers or multiple stages of electromagnetic focused intensifiers. The first would require 4:1 or greater reduction in channel size to perhaps 5 microns diameter. The latter would increase focus power requirements by the square of the diameter increase resulting in increase from the 50 watts of the 50 x 50 mm SEC/ Orthicon to 5 kw for a 500 x 500 mm sensor per stage.

f. Shot noise of para. 8 can also come from the thermionic cathode and may or may not be the dominant noise source in a scanned integrating target sensor. Also, the ultimate noise performance of solid state devices such as buried channel CCD's is still to be determined.

g. Equation 5.6 is given as proportional to $C^2 \Delta f^3$ by several references including L. D. Miller of R.C.A. in Photoelectronic Imaging Devices, Volume 1, Plenum Press, 1971. This form has been experimentally verified and has obvious implications on the requirements of selecting frame time, line number, and resolution elements to maximize signal to noise by selecting the proper Δf.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 2.19

1. TECHNOLOGY REQUIREMENT (TITLE): High Resolution Photon Counting Detector PAGE 13 OF 14

Improve resolution over 300 arc sec FOV; improve dynamic range

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. W74-70369 Astronomical Sensors and Imaging Systems for Large Space Telescopes, Lawrence Dunkelman, GSFC, 301-982-4988.

b. W74-70358 (502-23-32) Astronomical Sensors and Imaging Systems for Large Space Telescope.

c. Contract No. NAS-5-20069 Large High Resolution Integrating TV Sensor for Astronomical Applications, GSFC.

d. W74-70358 (502-23-32) Automated Data Handling Techniques and Components, GSFC, D. H. Schaefer, (301)982-5184.

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Provide means for compensating for relative shifts between guidance focal plane and high resolution camera focal plane to minimize angular shifts during total exposure period.

b. If successive readout and superposition of images used in photon counting mode, image registration to 0.1 pixel.

c. Angular stability during exposure, preferably to 0.1 of resolution element or pixel; at least to one resolution element; enables better and more accurate photon counting per spatial element.

d. Selectable bandpass filter, adjustable from 0.1 nm to 10 nm at any wavelength.

e. Parallel photon counters with a dynamic range of 10^7 are needed for each element of the 20,000 by 20,000 pixel detector array. A very large, real time, digital computer is required for this purpose and, to be usable, both the sensor readout and the computer cycle time must be sufficiently fast so as to ensure a less than 10% probability of a photon event per picture element per frame from the object under observation.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-2.19

1. TECHNOLOGY REQUIREMENT (TITLE): High Resolution Photon Counting Detector   PAGE 14 OF 14

Improve resolution over 300 arc sec FOV; improve dynamic range

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Tech. & Parametric Trades Analysis																			
2. Design & Construction of Feasibility Model																			
3. Feasibility Tests & Eval																			
4. Design & Construction of Full Scale Model																			
5. Sortie Flight Tests (Partial Coverage)																			
APPLICATION																			
1. Design (Ph. C)								Updating											
2. Devl/Fab (Ph. D)								Reintegration											
3. Operations*					T1 T3	o	o		T2	● ●	●	● ●	●	● ●	●	●	●		
4.							T4												

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE						T												
NUMBER OF LAUNCHES						T3		T4	T3	T1 T2 T4	T2	T1 T2	T2 T4	T1 T2 T3	T2	T2	T2	17

14. REFERENCES:

a. Summarized NASA Payload Descriptions, Automated Payloads, Level A Data, PD, NASA MSFC, July 1974.

b. Summarized NASA Payload Descriptions, Sortie Payloads, Level A Data, PD, NASA MSFC, July 1974.

c. NMAB, 287, Materials for Radiation Detection, National Materials Advisory Board, Jan. 1974, pages 79 thru 98.

Legend:

● = Flight utilized, Sortie flights.
o = Flight not utilized; advanced development results available for later flights.
T1 = AS-03-S, Deep Sky UV Survey Telescopes
T2 = AS-04-S, 1m Diffraction Limited UV Optical Telescope
T3 = AS-01-A, Large Space Telescope (Instr. may not be used in initial LST flight)
T4 = AS-14-A, 1m UV-Optical Telescope

* Different payloads require different size detectors.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.20

1. TECHNOLOGY REQUIREMENT (TITLE): Visible UV Polarimeter PAGE 1 OF 4
Improved circular and linear polarization sensitivity and resolution

2. TECHNOLOGY CATEGORY: Sensor

3. OBJECTIVE/ADVANCEMENT REQUIRED: Measure linear and circular polarization to 1% at a number of wavelengths between 0.13 and um of source brightness of $< m_v = 20$

4. CURRENT STATE OF ART: Polarization at source brightness of $m_v \sim 20$ has been measured to about 10%.

HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

According to Perkin Elmer Report No. 9800: Polarizers which provide an undeviated beam such as the Rochon or Senarmont prism[e], a pile of plates[f], or mirror systems[i] offer advantages in the techniques of detection and measurements.[n] These advantages relate to the fact that the polarizer can be rotated while the detector remains fixed, all without the use of auxiliary reflectors.

For internal calibration purposes a Lyot-type depolarizer[o] should be flipped in the beam between the telescope output and the polarizing prism. A Lyot depolarizer consists of two retardation plates, one twice the thickness of the other, with the axis of one oriented at a 45- degree angle to that of the other. The depolarization is effective if the plates are thick enough to provide a 200π change in the retardation angle for changes in λ defined by the bandwidth. The Lyot depolarizer is not effective in monochromatic light.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. During the past decade the measurement of polarization has become increasingly important in stellar astronomy. These measurements are usually made because of their usefulness in establishing the presence and nature of magnetic fields - either the general field of the galaxy or extragalactic nebulae or more restricted fields, such as that found in the Crab Nebula or in M87[a].

b. Benefiting payloads are AS-04-S, 1 m Diffraction Limited Visible/UV Telescope and AS-01-A, Large Space Telescope, with which the polarimeter may be used in space.

c. The polarization measurements will enable better analysis of stellar atmospheres and intersteller dust clouds.

d. While tests in the laboratory are indicative final tests will be with a 1 meter telescope for a sortie flight in space. For initial technology verification an Aries rocket launch can be used.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.20

1. TECHNOLOGY REQUIREMENT(TITLE): Visible UV Polarimeter PAGE 2 OF 4

Improved circular and linear polarization sensitivity and resolution

7. TECHNOLOGY OPTIONS: According to Perkin Elmer Report No. 9800

Only polarimeters in the range of wavelengths from 0.13μ to 1.0μ will be considered. Because of the special nature and severity of the problems relating to wavelengths below 0.13μ, they will not be dealt with here.

Piles of plates or mirror systems, because of their inefficiencies, will not be considered because of recent developments in a 'double' Rochon prism[f]. This prism consists of MgF_2 crystals and is good for the range 0.13μ to 0.30μ. A double Rochon can be fabricated more easily and has a smaller optical path which allows less absorption loss.

For the wavelength range 0.30μ to 1.0μ, calcite is a good material. It has a high bi-refringence and consequently higher prism angles, which make for easier fabrication. The transmission is good for the whole range (0.3μ to 1.0μ). For color polarimetry it is desirable to provide five band pass filters, equally spaced in $1/\lambda$, that is, filters centered at: 0.322, 0.379, 0.463, 0.500 and 0.813 microns, all of half-width 0.47 recriprocal microns.

Measurements may be carried out with any one of the five filters or with the Lyot depolarizer.

8. TECHNICAL PROBLEMS:

a. Filters for the range 0.13μ to 0.3μ are difficult to make and require development. Metal dielectric types have been made by Bates and Bradley[k], and by Baumeister[l].

b. Polarization by switch mirror or offset optics.

c. Telescope mirror coatings as well as telescope mirror surface finishes and contours.

9. POTENTIAL ALTERNATIVES:

a. Any asymmetry introduced by the coating process will cause substantial polarization errors. If the evaporation sources do not provide enough symmetry under static conditions, the mirror must be rotated during evaporation. The evaporation times are very short so that high speed rotation would be needed. This requirement is relaxed if the asymmetry is periodic and of many periods in the course of 1 revolution.

b. Polarization Filters of Technology Req. C2.22 plus improved photon detector of Technology Requirement C-2.19.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. W74-70658 (188-78-56) Design, Analysis and Evaluation of the Large Space Telescope Optical Instrument System, GSFC. A. B. Underhill, (Ph: 301-982-5101)

b. W74-70633 (185-50-63) Theoretical Studies on Neutron Stars and Gravitational Waves, Goddard Institute for Space Studies, New York, V. M. Canuto (Ph: 212-866-3200)

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Flip on switch mirror compensation. The flip mirror should be compensated for by another mirror using the same incidence angle as the flip mirror but with its plane of incidence normal to that of the flip mirror. Electronic compensation is out of the question because the amount of correction is far greater than the polarization to be observed.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.20

1. TECHNOLOGY REQUIREMENT (TITLE): Visible UV Polarimeter PAGE 3 OF 4

Improved circular and linear polarization sensitivity and resolution.

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Trades & Theoretical Analysis	–																		
2. Prelim. Design of Exp. Model	–																		
3. Fabrication of Exp. Model		–																	
4. Laboratory Test & Evaluation			–																
5. In Space Tests & Evaluation				T		•													
APPLICATION																			
1. Design (Ph. C)				–															
2. Devl/Fab (Ph. D)					–														
3. Operations									T1	•	•	•	•	•	•	•	•		
4.					T2	↑	–	–	↓↑	–	–	–	–	↓↑	–	–	–	–	↑

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE				T														
NUMBER OF LAUNCHES						T2			T2	T1	T1	T1	T1	T1 T2	T1	T1	T1	11

14. REFERENCES:

a. Hiltner, W.A., ed.: Astronomical Techniques, University of Chicago Press, 1962, Chapter 10.

b. Greenberg, J. Mayo, Meltzer, A.S.: Astrophysical Journal, Vol. 132, 1960.

c. Coyne, G. V., Gehrels, T.: Astronomical Journal. Vol. 71, No. 6, June, 1966, pp. 355-363.

(Continued on page 4)

LEGEND:

- • = Sortie Operations
- – = Automated Operations
- T = Technology
- T1 = AS-04-S, 1m Diffraction Limited UV Optical Telescope.
- T2 = AS-01-A, Large Space Telescope (Instrument may not be used in initial LST flight)

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.20

1. TECHNOLOGY REQUIREMENT (TITLE): Visible UV Polarimeter PAGE 4 OF 4

Improved circular and linear polarization sensitivity and resolution

14. REFERENCES (Continued)

d. Gehrels, T., and Teska, Thomas M.: Applied Optics., Vol. 2, No. 1, January 1963, pp. 67-77.

e. Steinmetz, D. L., Phillips, W. G., Wirick, M., and Forbes, F. F.: Applied Optics. Vol. 6, No. 6, June 1967, pp. 1001-1004.

f. Bird, G. R., Shurcliff, W. A. Shurcliff, J.: J. Opt. Soc Amer. Vol, 37, No. 818, pp. 235-237.

g. Perkin Elmer Engineering Report 9800, Large Telescope Experiment Program, Apr. 24, 1970.

h. Walker, William C.: Applied Optics. Vol. 3, No. 12, December 1964, pp. 1457-1459.

i. Rosenbaum, G., Feurerbacher, B., Godwin, R. P., Skibowski, M.: Applied Optics, Vol. 7, No. 10, October 1968, pp. 1917-1920.

j. Hamm, R. N., MacRae, R. A., Arakawa, E. T.: J. Opt. Soc. Amer. Vol. 55, No. 11, November 1965, pp. 1460-1463.

k. Bates, B. and Bradley, D. J.: Interference Filters for the far UV (1700Å to 2400Å), J. Appl. Opt. Vol. 5 No. 6, p. 971, June 1966.

l. Baumeister, P. W., Costich, V. R., Pieper, S. C.: Paper WB11, Pres. Opt. Soc. Amer., October 7, 1964.

m. Hiltner, W. A., ed.: Astronomical Techniques, University of Chicago Press, 1962, Chapter 10.

n. Pernicone, C. V., Hemstreet, H. S., Patrick, K. W.; Arizona Photopolarimeter Telescope - OAO, Vol. 1, Perkin-Elmer Engineering Report No. 8527 (I), October 26, 1966.

o. Billings, Bruce H.: J. Opt. Soc. Amer. Vol. 41, No. 12, December 1951, pp. 966-973.

p. Steinmetz, D. L., Phillips, W. G., Wirick, M., and Forbes, F. F.: Applied Optics. Vol. 6, No. 6, June 1967, pp. 1001-1004.

q. Astronomical Techniques by W. A. Hittner, pages 107 to 125, Chapter 5 on Measurement of Stellar Magnetic Fields by H. W. Babcock, Mount Wilson and Palomar Observatories. 1962.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.21

1. TECHNOLOGY REQUIREMENT (TITLE): Large Photocathode Electrographic Camera; Improved resolution, higher sensitivity at selected wavelengths in 100 to 400 nm range, with long wavelength cutoff. PAGE 1 OF 5

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development of magnetically focused electrographic camera capable of 5 to 10 micrometer resolution over a 200 nm diameter field.

4. CURRENT STATE OF ART: Electronographic cameras have produced 10 micrometer resolution over a 100 mm field.

HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

Electronic cameras evolving from the initial Lallemand electronic camera (Lallemand, Duchesne, and Walker, 1960) to the electronographic cameras produced by George R. Carruthers for use with 70 mm film provide the technology base for development of a larger magnetically focused electrographic camera. The desired electrographic camera converts a UV image at a 200 mm or larger photocathode into a photoelectron image which is accelerated by voltage through a magnetic field (up to 20000 gauss with a super conducting magnet) to an electron sensitive emulsion.

Several wavelength bands are being considered: one at 220 nm, one at 150 nm, and one including Lyman Alpha. Subarc second angular resolution over a 5° diameter field is desired assuming a focal length of 25 meters.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Resolution and sensitivity are a function of the angular, spectral, and intensity resolution capabilities of the wide field telescope and the electrographic camera. (See Page 3, Technology Options.)

b. The payloads benefiting from the development of the electrographic camera include: AS-03-S, Deep Sky Survey Telescope; AS-13-A, UV Survey Telescope; AS-31-S, Combined AS-01, -03, -04, -05-S. An earlier payload AS-42-S Far UV Electrographic Schmidt Camera/Spectrograph could also benefit.

c. The electrographic camera technology development will enable direct imaging of unreddened B0 stars to $m_V = 21$, $m_V = 11$ with objective grating and 0.1nm spectral resolution and $m_V = 17$ with objective grating and 10 nm spectral resolution in 15 minutes exposures.

The camera in conjunction with a 0.75 m to 1 m UV Survey Telescope will detect and measure cosmic sources rich in UV radiation, measure properties of intersteller media, provide uniform UV reference data (magnitudes & spectra), enable studies of wide angle diffuse sources, and provide updating and a UV complement to the Palomar Sky Survey. (See continuing discussion on Page 2)

TO BE CARRIED TO LEVEL 7

1. TECHNOLOGY REQUIREMENT (TITLE): Large Photocathode Electrographic Camera; Improved resolution, higher sensitivity, at selected wavelengths in 100 to 400 mm range, with long wavelength cutoff.

6. RATIONALE AND ANALYSIS: (Continued)

c. (Continued)
Both Deep Sky Survey Telescope and 1 Meter Diffraction – Limited Telescope will benefit by the increased information storage capacity 4×10^8 pixels/field dia. of this detector which will be 4 times greater than that of existing electrographs. Such a detector is ideally mated to the ability of the Deep UV telescope to produce better than 1 arc sec images over a 5° field diameter and to the ability of the 1 meter diffration-limited telescope to produce 0.2 arc sec images over a 1° field.

Photographic film already has this information storage capability but the electrographic camera has several additional advantages:

(1) Greater quantum efficiency by a factor of at least 10 (this is a critical factor).

(2) Greater resolution thus making possible a more compact, less massive telescope.

(3) Long wavelength cutoff which eliminates noise effects from solar radiation in optical wavelengths.

(4) A linear response curve over broader density ranges which allows easier conversion of the data to intensities and also gives a greater dynamic range.

d. Although some testing can be accomplished in the laboratory or the ground, final testing is expected in orbit on a shuttle sortie mission. Initial laboratory tests by 1976 should indicate feasibility. An experimental smaller model may be flown on an Aries rocket to deomonstrate technology.

1. TECHNOLOGY REQUIREMENT (TITLE): Large Photocathode Electrographic Camera; Improved resolution, higher sensitivity, at selected wavelengths in 100 to 400 mm range, with long wavelength cutoff.

7. TECHNOLOGY OPTIONS:

The electrographic cameras utilize UV to electron conversion, acceleration of photo electrons to strike a photographic emulsion instead of a phosphor. For each photoelectron, several grains in the emulsion become exposed. As mentioned before, the technique dates back to 1960 and the concept back to 1936. However, new techniques such as better photocathodes and means of obtaining stronger and more uniform magnetic focusing or guiding fields open the way for improved performance. Since photoelectrons accelerated from the photocathode produce identifiable tracks on the nuclear or equivalent film, the device may be used for counting electrons, and indirectly photons.

Magnetically-focused and electrostatically focused image tube options exist. The image quality of magnetically focused image tubes is generally superior to that of electrostatically focused types. However, magnetically focused types require an external, cylindrical focusing coil or a permanent magnet and the voltage applied to the tube should be well regulated and filtered. As a result magnetically focused image tubes are normally heavier and more complex than those using electrostatic focus. But a 200 mm diameter electrostatically focused camera is very difficult to make.

When the magnetic field is increased to about 20000 gauss, such as in a small super-conducting magnet, the photoelectrons tend to follow the magnetic field lines arranged to extend uniformly from the photocathode to the film or output image phosphor. Consequently very little degradation would occur in the UV photon to photoelectron conversion and acceleration process. The photocathode surface can be selected to match the telescope optical surface without degradation of the electron image.

For nonfilm alternatives at the output image plane, silicon, or other charge coupled devices have developed into the most promising approach to solid state imaging. The basic feasibility has been demonstrated for small numbers of image elements at correspondingly low scan rates. Some problem with surface states with life times near the inverse of the line scan frequency tend to reduce transfer efficiencies. Unless a technological breakthrough occurs, image resolution and acceptability will be compromised. (Picture elements per frame are currently less than 10^6, vs 10^8 to 4×10^8 for the advanced electrographic camera.)

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.21

1. TECHNOLOGY REQUIREMENT(TITLE): Large Photocathode Electrographic Camera, Improved resolution, higher sensitivity, at selected wavelengths in 100 to 400 mm range, with long wavelength cutoff. PAGE 4 OF 5

8. TECHNICAL PROBLEMS:

a. Non uniform deposition of a 200 mm photocathode is biggest problem.
b. The quality of electron focus on the nuclear emulsion limits resolution and is the 2nd largest problem.
c. The ideal electrographic camera writes directly on film but requires access for loading and unloading film.
d. Interaction with other payload elements in AS-31-S.

9. POTENTIAL ALTERNATIVES:

a. Multistage, fiber optically coupled, electrostatically focused image intensifiers. (However, these have greater threshold noise and are very difficult to make in 200 mm size.)
b. UV-to-electron converter/microchannel plate/output phosphor combinations for direct writing on film.
c. UV-to-electron converter/microchannel (Chevron) plate and charge coupled device (CCD) detector array. (Gains between 10^4 - 10^7)
d. Magnetically focused image intensifier (165 mm dia, phosphor feeds fiber optics to enable contact film recording.)

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

W74-70369, Astronomical Sensors and Imaging Systems for Large Space Telescopes, Lawrence Dunkleman, 301-982-4988, GSFC.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Internal Electrographic camera contamination/vacuum control.
b. Nuclear radiation suppression (protons, electrons, bremmstrahlung, and secondaries). (However, intense magnetic fields may provide magnetic shield effect around electrographic camera.)
c. Deep Sky Survey Telescope (0.75 to 1m dia), resolution better than 0.5 arc sec.
d. Guiding on 9th magnitude stars to ± 0.1 arc seconds stability.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-2.21

1. TECHNOLOGY REQUIREMENT (TITLE): Large Photocathode Electrographic Camera; Improved resolution, higher sensitivity, at selected wavelengths in 100 to 400 mm range, with long wavelength cutoff. PAGE 5 OF 5

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. User Needs Analysis	—																		
2. Parametric & Design Analysis	—																		
3. Prototype Design		—																	
4. Lab Tests & Improvement		—	—	—															
5. Test on Aries rocket																			
6. Test in Sortie Shuttle					●														
APPLICATION																			
1. Design (Ph. C)		—	—																
2. Devl/Fab (Ph. D)			—	—															
3. Operations (Primary)				T1	● T3	●●	●	●	●	●●	●●●●	●●●	●●	●●●	●●	●●	●●●		
4. Alternate				T2	↴	↴				↴	↴	↴		↴			↴		

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE		T																
NUMBER OF LAUNCHES					T1 T2 T4	T1 T2 T3 T4	T4 T3	T3	T3	T1 T2 T3	2T1 T2 2T3	T1 T2 2T3	2T3	T1 2T3	2T3	2T3	T1 T2 2T3	33*

14. REFERENCES:

a. Lallemand Electronic Camera, pages 347 to 353, Astronomical Techniques, edited by W. A. Hiltner, 1962.

b. Conference, Dr. Karl G. Henize with E. S. Saari, Oct. 18, 1974, at JSC.

c. Summarized NASA Payload Descriptions, Sortie Payloads, MSFC PD, July 1974.

d. Summarized NASA Payload Descriptions, Automated Payloads, MSFC, July 1974.

e. Applications note E20, ITT Electroproducts Div., USN F3361570-C-1826 and -1735 (with improved window and cathode).

Legend:

T1 = AS-03-S, Deep Sky UV Survey Telescope

T2 = AS-13-A, UV Survey Telescope

T3 = AS-31-S, Combined AS-01, -03, -04, -05-S.

T4 = AS-42-S, Far UV Electrographic Schmidt Camera/Spectrograph

T = Technology

● = Sortie Operations

↴ = Automated Operations

*The automated is a backup for sortie flights. AS-31-S flights may reduce the requirements for AS-03-S flights.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.22

1. TECHNOLOGY REQUIREMENT (TITLE): IR, Visible, UV, XUV Universal Filters; Selectable Pass Bands in each Portion of the Spectrum, with Low Loss, Constancy of Loss, Accuracy of Loss

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Provide a readily selectable universal adjustable bandpass filter for each range (IR: one to 10 μm, passband from 1000 to 1 μm; Visible 0.1 to 10nm passband from 1000 to 400 nm, 0.1 to 10nm passband from 400 to 90nm; 0.01 to 1nm passband from 100nm to 10nm).

4. CURRENT STATE OF ART: A transmission filter capable of wavelength selection between 420 and 700 nm with passband variable from 0.01 to 0.06nm has been built by Carl Zeiss, Oberkochen, West Germany in 1974.

HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

Readily adjustable bandpass filters with low loss (less than 25%) are needed to cover the IR, Visible, UV and XUV spectral ranges to enable band limited imaging or the equivalent of imaging spectrophotometer. The Carl Zeiss Company in Germany has produced a prototype universal bi-refringent filter. Reflective or transmissive techniques are applicable. Imaging detector resolution shall not be degraded more than 0.5 resolution element.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Electronographic, electronic, and film image detection methods can be utilized for narrow band spectral imaging or imaging spectrophotometry in a large number of optical instruments.

b. Payloads that directly benefit include sortie and automated astronomy, solar-physics, earth observation, earth and ocean physics disciplines. Payloads with potential benefit are those with imaging requirements in the high energy astrophysics, atmospheric and space physics and in the planetary and lunar discipline.

c. Improved filters enable rejection of stray light, analysis of source constituents, and identification by spectral signatures.

d. Final tests will be accomplished in space on sortie flights. Initial test will be accomplished on Aries rocket or HEO-B spacecraft.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.22

1. TECHNOLOGY REQUIREMENT(TITLE): IR, Visible, UV, XUV Universal Filters; Selectable Pass Bands in each Portion of the Spectrum, with Low Loss, Constancy of Loss, Accuracy of Loss PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

Neutral density transmission filters as well as advance bi-refringent filters need to be considered in trades. The universal filter will include programmable control to select any of the wavelengths and the passband around the wavelength within the range of any one of the universal filters. In addition to the described pass band characteristics, each universal filter will have polarization analyzer segments that can be inserted into the light path to provide magnetically related information.

8. TECHNICAL PROBLEMS:

a. Imaging with a dynamic range greater than 256 (8 bits).

b. Accountable losses in filter chain, good to 0.1 magnitude.

c. Minimun distortion in optical path.

9. POTENTIAL ALTERNATIVES:

a. Individual filters per instrument.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

TBD

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Optical Telescope Technology. (See C-1.4)

b. High Resolution Photon Detector. (See C-2.19)

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-2.22

1. TECHNOLOGY REQUIREMENT (TITLE): IR, Visible, UV, XUV Universal Filters; Selectable Pass Bands in each Portion of the Spectrum, with Low Loss, Constancy of Loss, Accuracy of Loss PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Survey & Analysis of Applications	—																		
2. Concepts Trades		—																	
3. Design of Exp. Models per Band		—																	
4. Fab. of Exp. Models			—																
5. Test & Evaluation				—	—	—	—												
APPLICATION																			
1. Design (Ph. C)				—	—														
2. Devl/Fab (Ph. D)					—														
3. Operations					—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				T														
NUMBER OF LAUNCHES*					4	4	4	4	4	4	4	4	4	4	4	4	4	52

14. REFERENCES:

a. Universal Birefringent Filter, Carl Zeiss, Oberkochen, West Germany.

Legend:
T = Technology

*These are the directly benefiting payloads in the astronomy, solar physics, earth observations and earth and ocean physics disciplines, see paragraph 6b above.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.23

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Atmospheric Sensors Group - Improved Area coverage, spatial and spectral resolution, selectivity, and measurement accuracy PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Obtain atmospheric and pollution signature data versus location (0.9 to 10 km horizontal/vertical resolution). Improve calibration accuracy to 0.2% for CO_2 and 1% for other constituants, solar constant to 0.5%, temperature to $\pm 1.5^{o}$K.

4. CURRENT STATE OF ART: Calibration accuracy 3 to 5% for some constituents; up to 30% for most of the pollution constituents; altitude 2 to 3 km, horizontal accuracy 2 to 3 km.

HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY

The advanced atmospheric sensor group will include an improved ozone/sun polarimeter, a limb atmospheric composition radiometer, an air pollution sensor, and a high speed interferometer. Improvements include greater spatial coverage by faster sequencing of channels, application of image motion compensation, better data compression (coding), improved instantaneous field of view, greater collector area (hence better sensitivity), relocation and resizing of spectral bands, improvement of detector sensitivities together with coolers or closed cycle refrigeration. A solar extinction photometer is expected to be used to obtain data on the complex refractive index and size distribution of atmospheric aerosols. A radiative budget monitor will be added to the instrument complement to obtain the true atmospheric absorption, independent of and separate from scattering. Equipment measurements are needed for particulates.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. An improved set of atmospheric sensing (particularly pollution sensing) instruments can be evolved from currently planned gas filter correlation analyzer, IR correlation interferometer, IR optical interferometer, photopolarimeter, solar extinction photometer, radiative budget monitor instruments concepts. Considerable opportunity exists for consolidation and on-board cross correlation.

b. The primary payload benefitting from the development of an advanced atmospheric sensors groups is EO-56-A Environmental Monitoring Satellite. However some atmospheric sensing instruments will (EO-09-A Synchronous Earth Observatory Satellite and EO-08-A Earth Observatory Satellite).

c. The advanced set of atmospheric sensors will enable identification and monitoring of atmospheric pollutants, distribution of ozone, aerosols, measures of concentrations of ozone, nitric oxide, sulphur dioxide, nitric acid, nitrogen dioxide methane, and freons as well as measurements of related atmospheric conditions.

d. Final proof of achievement of capability is test on a sortie or automated space payload against aircraft and balloon measurements.

Initial technology needs can be demonstrated on an Atlas/Centaur flight.

TO BE CARRIED TO LEVEL 8

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DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.23

1. TECHNOLOGY REQUIREMENT(TITLE): Advanced Atmospheric Sensors Group - Improved Area coverage, spatial and spectral resolution, selectivity, and measurement accuracy

7. TECHNOLOGY OPTIONS:

Existing instrument concepts cannot provide all of the required measurements; hence vigorous development of sensors for identification of atmospheric constituents as well as improvements in accuracy for measurements of quantity and location of pollutants is needed. Calibration accuracy should improve from 5% to 1%. Instantaneous field of view should improve to enable spatial resolution to 0.9 km and identification of polluting sources to 15m. Internal calibration techniques are required on all visible and IR sensors. Constituent measurements will require use of correlation instruments for measurements in the troposphere.

(Continued on page 3)

8. TECHNICAL PROBLEMS:

a. Increased real time data relay capability up to 30Mb/s initially and to 120Mb/s later.
b. Simpler data reduction software and techniques to reduce computational complexity.
c. Faster integration times.
d. Decreased instantaneous field of view to help pinpoint source locations.

9. POTENTIAL ALTERNATIVES:

a. Alternative atmospheric sensing group: gas filter radiometer/correlation interferometer, optical filter radiometer, IR pressure modulated radiometer, UV/ozone monitor, solar extinction photometer, radiative budget monitor, photopolarimeter, THIR IR Radiometer, and a scanning spectroradiometer.
b. Information comparable to that obtained for gaseous pollution should be obtained for particulate pollution by a complementary set of instruments.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

W74-70476 Atmospheric Pollution Sensing, C. B. Graves, LaRC
W74-70450 Numerical Simulation, Pollution Transport, Eugene S. Love, LaRC
W74-70452 Remote Sensing Techniques for Atmospheric Structure and Surface Condition Relevant to Meteorology, W. A. Harris, GSFC.

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Increased data handling capability, up to 120Mb/s (on board data processing).
b. Attitude determination to 0.002°; spacecraft position data to ≤15m is desirable (at least 0.3 to 1 km is required).
c. Long lifetime, low temperature cooling.
d. Temperature profile correlation methods.
e. Multiple sensor registration of view footprints.
f. Solar energy and earth albedo monitors.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-2.23

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Atmospheric Sensors Group - Improved Area coverage, spatial and spectral resolution, selectivity, and measurement accuracy PAGE 3 OF 4

7. TECHNOLOGY OPTIONS: (Cont'd)

The key instruments - the correlation interferometer, the gas filter analyzer, and the IR interferometer - will certainly be improved over the next several years with the most improvement being expected in the correlation interferometer and the least in the IR interferometer. There is certainly opportunity for simultaneous use of a combination of these instruments. It should be noted that the measurement time is quite different for these three instruments - the correlation interferometer being the fastest and the IR interferometer the slowest. It should also be noted that the signals reaching the instruments and hence their sensitivities are functions of the wavelength, the species burdens, the atmospheric temperature profile, the surface temperature, the surface reflectivity, the surface emissivity, and other factors.

Another fundamental capability is provided by the radiative budget monitor (not the Earth albedo monitor). This instrument can only measure the net radiation flux (or the upward and downward fluxes the difference of which yields the net flux). This quantity is influenced by both physical processes of absorption and scattering from both gases and particulates. However, the quantity of interest is the true atmospheric absorption, i.e., independent of and separate from scattering. It is this absorption that determines the atmospheric heating. JPL has developed a true absorption radiometer, an engineering model has been constructed, and preliminary test conducted in JPL's ambient air.

The absorption data provided by the near IR interferometer are usually interpreted (incorrectly) without regard to the effects of scattering by atmospheric gases and particles. However, since scattering alone (not absorption) induces polarization in the light field, the measurement of polarization should in principle enable one to assess the scattering effects. This information can be used to both study the scatterers for themselves and eliminate their effects in interferometric data. Unfortunately the spectral resolution of the photopolarimeter is too coarse compared to that of the interferometer (typically it is 10^3 times coarser). What is needed is an interferometer-polarimeter that will provide both the radiance and the polarization with the same spectral resolution. JPL has developed a prototype model of such an instrument with the help of the University of Arizona. The first polarization spectra (wavelength range 0.8 to 2.7 μm, spectral resolution 0.5 cm^{-1}) of Venus were obtained with this instrument at the telescopes of Steward Observatory and Mexican National Observatory (Baja California).

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-2.23

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Atmospheric Sensors Group - Improved Area coverage, spatial and spectral resolution, selectivity, and measurement accuracy   PAGE 4 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Concepts analysis & trades																			
2. LaRC parametric design																			
3. Fabrication of integratable experimental instruments																			
4. Test & Evaluation																			
5. Planning & Recommendation																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations					E1														
4.				E2		E3													

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE			T															
NUMBER OF LAUNCHES					E2	E1 E2	E1 E2 E3	E1 E2	E3	E2	E1 E3	E1 E2	E1 E2 2E3	E1	E2 2E3	E1	E1 E2 2E3	27

14. REFERENCES:

a. An Evaluation of Technology Needed for Earth Environment Monitoring (Air and Water), by Wendell G. Ayers, Dr. David E. Bowker, Dr. L.R. Greenwood and Associates at LaRC, 1974.

b. Study for Office of Applications of New Instrumentation Initiative for the Environmental Technology Satillite, LaRC Staff, May 31, 1974.

c. Comments from Dr. M. H. Bortner, General Electric, 20 Jan. 1975.

d. Comments from Dr. Alain L. Fymat, JPL, 24 April 1975.

Legend:

T = Technology

— = Automated Operations

E1 = EO-56-A Environmental Monitoring Satellite

E2 = EO-08-A Earth Observatory Satellite

E3 = EO-09-A Synchronous Earth Observatory Satellite.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-2.24

1. TECHNOLOGY REQUIREMENT (TITLE): G-JITTER DETERMINATION PAGE 1 OF 3

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED: To define the G-Jitter environment, determine the level expected aboard Spacelab, develop instrumentation for accurate measurements, and relate it to objectives of proposed experiments.

4. CURRENT STATE OF ART: Some measurements of perturbations were conducted on Skylab. These should serve as a reference point in the analysis.

HAS BEEN CARRIED TO LEVEL 2

5. DESCRIPTION OF TECHNOLOGY

G-Jitter is defined as an unsteady perturbation to the gravity field resulting from spacecraft maneuvers and/or mechanical vibrations. A need exists for determining the environment from which G-Jitter occurs. A determination of the G-Jitter levels expected aboard the Shuttle Space Lab system during planned experimentation must be made. One must ascertain the potential effects of disturbances on the results and conduction of typical experiments (ref. 2). Finally, instrumentation must be developed for accurate measurement of G-Jitter on a continuous basis as compared to current methods involving back-calculations of questionable accuracy. G-Jitter levels can render certain space experiments worthless. Electrostatic accelerometers of high sensitivity exist, but their adequacy in this application has not been evaluated fully.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The need for the above technology is a part of the LeRC overall program for convection oriented experiments aboard Spacelab. This technology should not only serve the proposed physics and chemistry experiments, but will be applicable to many others. The critical parameter which drives this technology is gravity. A knowledge of its magnitude is essential to the objectives of all proposed experiments. Its assessment will provide valuable design information. Without knowledge of the effect of G-Jitter on the possible experiments, their validity is in question.

The technology program should include a zero-G test of the measuring instrumentation aboard an Aerobee vehicle.

TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-2.24

1. TECHNOLOGY REQUIREMENT(TITLE): G-Jitter Determination PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

One approach would be to measure the position error-signal fluctuations in an electromagnetic (RF) positioning device. The test mass within the positioning device would consist of a low resistivity material.

8. TECHNICAL PROBLEMS:

1. Can the vibration spectrum of Shuttle Spacelab be defined locally?

2. Will the instrumentation be defined in a timely way?

3. Is there sufficient knowledge of vibration induced convection to define effects accurately?

9. POTENTIAL ALTERNATIVES:

Automated free-flying experiments as an alternative to manned Spacelab, however, many experiments require manned intervention.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

LeRC Physics and Chemistry Experiments Program requires the above technology for insurance that current focused development studies will result in study areas that can be handled from an experimental point of view.

RTOP 975-73-48

EXPECTED UNPERTURBED LEVEL 3

11. RELATED TECHNOLOGY REQUIREMENTS:

The work being conducted in the Space Processing Discipline concerning electromagnetic levitation is relevant to these measurement requirements. (See reference no. 4.)

DEFINITION OF TECHNOLOGY REQUIREMENT | NO. GE-2.24

1. TECHNOLOGY REQUIREMENT (TITLE): G-Jitter Determination | PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analyses																			
2. Math.Model Simulation																			
3. Instrument Design																			
4. Instrument Test																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE						Δ												
NUMBER OF LAUNCHES							2	3	3	3	3	3	3	3	3	3	3	32

14. REFERENCES:

1. Dodge, F. T.; etal: Fluid Physics, Thermodynamics, and Heat Transfer Experiments in Space. Final Report of the Overstudy of Committee. Southwest Research Inst., NAS3-17808.

2. Gebhart, B.: Random Convection Under Conditions of Weightlessness. AIAA J., Vol. 1, pp 380-383, 1963.

3. Bannister, T. C. Grudzka, P. G., Spradley, L. W., Bourgeois, S. V., Hedden, R. O., and Facemire, B. R.: Apollo 17 Heat Flow and Convection Experiments. Final Data Analysis Results, NASA TM X-64772, July 1973

4. "Design Analysis of Levitation Facility for Space Processing Applications", Final Report, Mod. No. 3 to Contract No. NAS-8-29680 (General Electric Co.).

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-2.25

1. TECHNOLOGY REQUIREMENT (TITLE): Mass Measuring Device PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Sensors

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop a mass measuring device for use in Spacelab scientific experiments where very small masses are involved and high accuracy is required.

4. CURRENT STATE OF ART: Zero gravity mass measuring devices have been used on Skylab for relatively large masses (50 gm)

HAS BEEN CARRIED TO LEVEL 2

5. DESCRIPTION OF TECHNOLOGY

A mass measuring device is required for use in Spacelab experiments in which "weight changes" are normally a principal measurement in normal gravity experiments. Combustion experiments involving solid or liquid burning are a good example. Masses as small as one to two grams are expected. Accuracy of two percent is anticipated.

The currently available systems consist of force-damped devices covering the range up to 50 gm (Skylab)

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The mass values and accuracies cited in (5) are determined from previous normal gravity experimentation.

The users of this device would be physics and chemistry experimenters, as a minimum. Other potential experiments which might require it would be in space processing.

The lack of this instrument could eliminate many worthwhile experiments.

Payloads: SSPD No.'s. ST-06S and SP-04S will utilize this technology.

Prototype models should be tested in a drop tower or free-fall trajectory aircraft test.

TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-2.25

1. TECHNOLOGY REQUIREMENT(TITLE): Mass Measuring Device PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

Measurement techniques may sense inertia (e.g. translational or rational acceleration due to a given force) or density/volume measurements (e.g. though microwave or x-ray penetration.

8. TECHNICAL PROBLEMS:

This device must use a technique which does not interact with experiment processes in a manner which influences experimental results. For example, a device which relys on oscillation to measure mass might induce artificial convection.

9. POTENTIAL ALTERNATIVES:

1. Measure mass before and after process, whenever possible.
2. Use induced-oscillation methods with very low accelerations and longer integration times.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

The Physics and Chemistry Experiment Program requires this device.

Work conducted under RTOP 975-73-48.

EXPECTED UNPERTURBED LEVEL 2

11. RELATED TECHNOLOGY REQUIREMENTS:

Analyses that may be pertinent to this technology are the subjects of "Particle Manipulation through Small Forces, in Zero Gravity", Beneficial Uses of Space Study (GE), NAS 8-28179.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-2.25

1. TECHNOLOGY REQUIREMENT (TITLE): Mass Measuring Device PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analyses		—																	
2. Design of Model			—																
3. Manufacture				—															
4. Free-Fall Tests					—														
5.																			
APPLICATION																			
1. Design (Ph. C)					—														
2. Devl/Fab (Ph. D)						—													
3. Operations							—	—	—	—	—	—	—	—	—	—	—		
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE						△												
NUMBER OF LAUNCHES							2	3	3	3	3	3	3	3	3	3	3	32

14. REFERENCES:

1. Study of Combustion Experiments in Space. Contract NAS3-17089- Report to be published.

2. Berlad, A.L.: Combustion for Experimentation in a Space Environment. Paper presented at Western Section of the Combustion Institute. California State University, Northridge, California, October 1974.

3. Catalog of Experiment Hardware. Contract NAS9-13559 - Report JSC-08650, November 1973.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. RL 2.26

1. TECHNOLOGY REQUIREMENT (TITLE): — PAGE 1 OF 5

Relativity Gyroscope (Extremely Low Drift Cryogenic Gyroscopes)

2. TECHNOLOGY CATEGORY: Sensor

3. OBJECTIVE/ADVANCEMENT REQUIRED: Gyroscope and Gyroscope Readout

4. CURRENT STATE OF ART: A gyroscope and readout method is being developed at Stanford U. and MSFC. Extensive gyroscope operation at low temperatures has been (continued on page 4)

HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

Conventional electrically suspended gyroscopes are deliberately made with unequal moments of inertia so that there is a preferred spin axis. Readout, therefore, depends on observing marks on the surface of the sphere.

A relativistic gyroscope cannot use this method because of the extreme requirements for homogenenity and sphericity of the rotor. The readout method requires measuring the direction and amplitude of the London Moment associated with the spinning superconductor. The spinning sphere generates a London Moment proportional to the angular frequency of the sphere. Total magnetic flux is 8×10^{-5} gauss Direction of field is determined by means of a superconducting loop and magnetometer. The currents will try to keep flux constant and can be detected to fractions of a microamp. A Josephson junction detection is built into the pickup loop to detect changes in magnetic flux equivalent to 1/10,000 of magnetic flux quantum. At 150 Hz, the total flux is 7800 flux quanta, and detection of changes is $1:10^8$ flux quanta.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Readout of precession in conjunction with changes in line of sight of telescope star tracker is required to accuracy of 10^{-3} arc sec/year. Accuracy is required to confirm or deny various theories of relativity and to make a unique measurement of the motional or Lense-Thirring effect.

b. AP-04-A Gravity and Relativity Satellite - LEO (Phy-2)

c. Payload experiment fails (cannot verify or deny theories of relativity) if readout accuracy of at least 3 arc sec/year is not attained.

d. Testing of one gyroscope concept is in progress at Stanford U. Testing of a second concept will be initiated at MSFC within six months.

TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. RI, 2.26

1. TECHNOLOGY REQUIREMENT(TITLE): Relativity Gyroscope — PAGE 2 OF 5

7. TECHNOLOGY OPTIONS:

The Stanford U. and MSFC gyroscope models employ somewhat different methods to spin the rotor. The options which affect gyroscope operation and manufacturing techniques, are being thoroughly studied. There are also options in the exact form of the Josephson junction detector which will influence readout accuracy.

Both Stanford U. and MSFC have full readout capability. Critical parameters which affect testing are: low magnetic field, low acceleration, low temperature, high sphericity rotor, and low gas pressure. (See Reference 1).

Hansen Laboratories of Stanford U. will continue their work in the areas of sophisticated optics and measurement of long term drift.

8. TECHNICAL PROBLEMS:

Figure 1 illustrates some of the tolerances to which the gyroscope must be constructed. Superconducting microbridges are required and have been constructed at MSFC of thickness on the order of 50 A using RF sputtering techniques. Junction widths on the order of 0.5 μ have been constructed using modified scanning electron microscope techniques. All technical problems appear solvable and models are being constructed.

9. POTENTIAL ALTERNATIVES:

Methods for measuring certain relativistic parameters, at reduced accuracies are: radar ranging and measuring gravity red shift by moving an EM signal in gravity field of the earth. However, with the possible exception of a binary pulsar observation experiment, the gyroscope will provide the only method for measuring the Lense-Thirring effect.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

No similar efforts other than at Hansen Laboratory, Stanford U. and MSFC.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Niobium microbridges for the gyroscope are being developed by MSFC, and for other uses by other laboratories.

b. Lightweight cryogenic storage vessel with hold time of one year in space at 1.6 to 2°K (see RI, 12.1)

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 2.26

1. TECHNOLOGY REQUIREMENT (TITLE): Relativity Gyroscope

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Options & parametric analysis (3.0 yr.)*																			
2. Design (3.0 yr.)*																			
3. Construct models (3.5 yr.)*																			
4. Test models (4.0 yr.)*																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

On-going effort. Possible test of lesser model gyroscope in Spring 1975 if launch available.

NOTE: Technology need date not being met according to present schedule.

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
TECHNOLOGY NEED DATE				▼													
NUMBER OF LAUNCHES						1		1									2

14. REFERENCES: * As presently scheduled.

1. C.W.F. Everitt, the Gyroscope Experiment, International School of Physics - Enrico Fermi Course 56 Ed: B. Bertotti (Acad. N.Y. 1974)
2. P. E. Wright, Refrigeration Systems for Spacecraft, RCA Advanced Technology, Publication of RCA Advanced Technology Laboratories, Camden, New Jersey, 1972
3. Lipa, J. A., et al, Research at Stanford on the Containment of Liquid Helium in Space by a Porous Plug and Long Hold-Time Dewar for the Gyro Relativity Experiment, W. W. Hansen Laboratory of Physics, Stanford University, Proceedings of the Cryogenic Workshop, MSFC, March 29-30, 1972
4. Everitt, C.W.F., and W. M. Fairbank, Applications of Cryogenic Techniques to the Stanford Gyro Relativity Experiment, W. W. Hansen Laboratories of Physic, Stanford University, Proceedings of the Cryogenic Workshop, MSFC, March 29-30, 1972
5. Technical discussion between Dr. E. Urban, MSFC, and P. R. Fagan, Rockwell International at MSFC on 17 October 1974.

(continued on page 4)

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

4. Current State of Art – continued

accomplished at Stanford U.; MSFC has made important advances in development of superconducting instrumentation for the readout system.

14. References – continued

6. Haldeman, L.B., and P. N. Peters, Niobium Bridges for SQUID Applications, 1974, Applied Superconditivity Conf., 9/30-10/2, 1974, Oakbrook, Illinois

7. Letter from Dr. E. Urban, MSFC to H. Ikerd, General Dynamics – Convair Aerospace, December 30, 1974

8. Letter From Dr. J. Lipa, Hansen Laboratories, Stanford U., to H. Ikerd, General Dynamics – Convair Aerospace, December 17, 1974

C.3

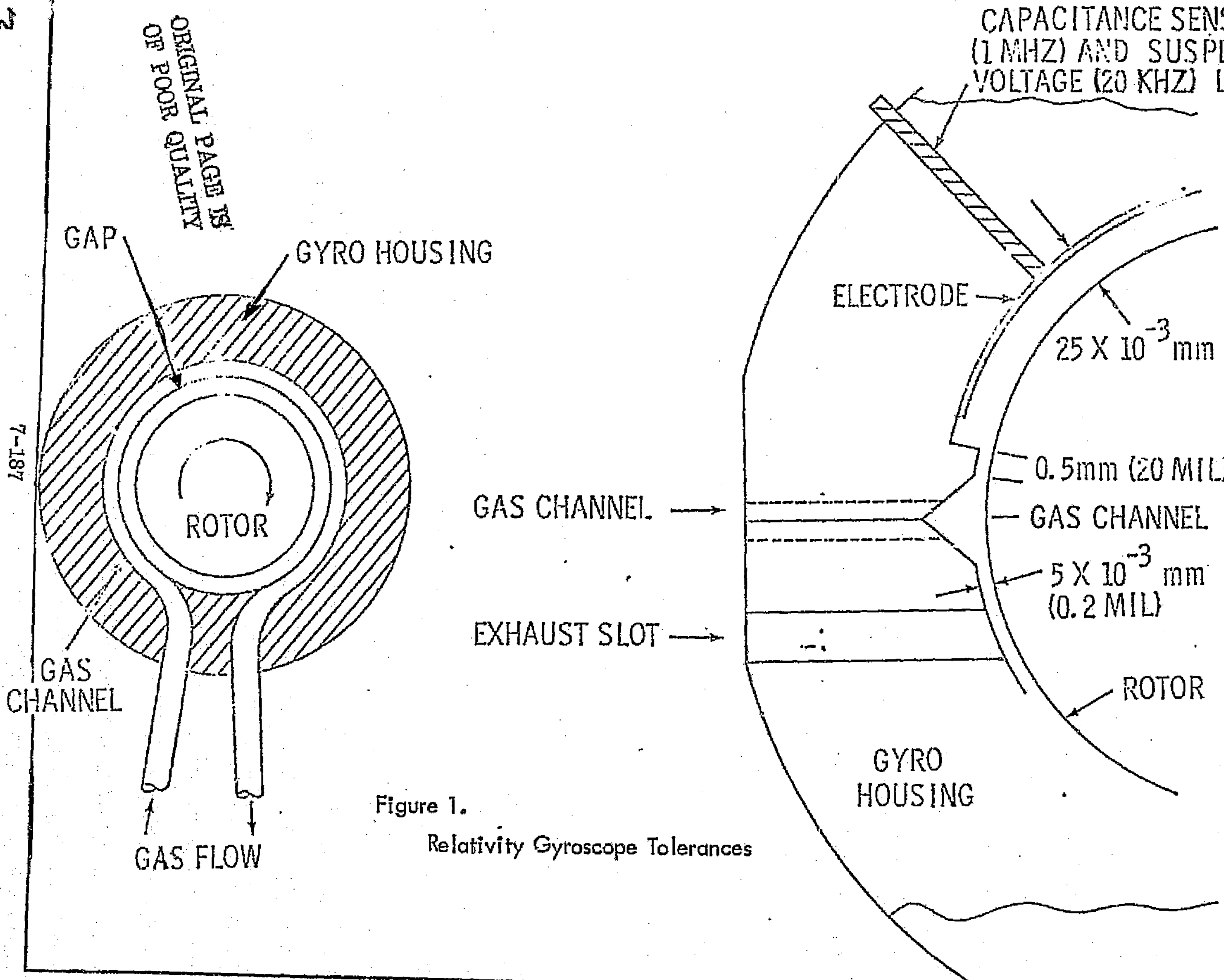

Figure 1.

Relativity Gyroscope Tolerances

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RL 3.1

1. TECHNOLOGY REQUIREMENT (TITLE): Lasers PAGE 1 OF 5

2. TECHNOLOGY CATEGORY: Generator

3. OBJECTIVE/ADVANCEMENT REQUIRED: Provide laser diode pumping for Nd:YAG laser communications system

4. CURRENT STATE OF ART: Breadboard model has been constructed

HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

Laser diodes are solid state devices which convert electrical energy into intense, nearly monochromatic light which can be used to pump an Nd:YAG laser. The technique which is used is to match Ga:Al:P laser diode outputs at 8100 Å (preferred wavelength), 8690 Å, and 8850 Å to the narrow 100 Å wide pumping band of the Nd:YAG laser. Because (1) the laser diode has a limited power output, and (2) the Nd:YAG laser requires 3 to 4 watts pumping to achive at 0.1 watt output, an array of laser diodes must be developed capable of high power pumping.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. The array size is defined as follows: It requires 3 to 4 watts of pump power at 8100 Å to excite the Nd:YAG lasers rod and to cause oscillation at the desired frequency as well as maintain a power output of 0.1 watt at 1.06 μ. The limiting power output of the laser diode at 8100 Å results in a need for laser diode arrays on the order of 80 to 160 diodes.

b. The Nd:YAG with the developed laser diode array will be used on the CN-05-5, Laser Communications Experiment.

c. Present NASA defined space communication data rates are on the order of 0.3 to 0.4 gigabits/sec with a post 1984 requirement of one gigabit/sec. The Nd:YAG laser is a ruggedized space qualified laser capable of data rates on the order of NASA requirements. The laser will communicate data from a low orbit satellite such as EOS to a geosynchronous satellite.

d. NASA expects engineering models of the Nd:YAG with laser diode pumping arrays to be available in the 1978 to 1979 time period. The requirements for flying the system are vague although standard thermal-vacuum and vibration testing will certainly be required.

Some technology transfer can be expected from Nd:YAG developments at USAF-WPAFB, and a proposed NASA/AF experiment (reference 1) to test a sun pumped Nd:YAG, and lamp pumped CO_2 laser in orbit as part of a communications system.

(continued on page 4)

TO BE CARRIED TO LEVEL 8 (see 6.c

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1. TECHNOLOGY REQUIREMENT(TITLE): Lasers

7. TECHNOLOGY OPTIONS:

A number of pumping options exist within certain limitations; they are:

a. Sun pumping – the sun is a high power standard source for collecting energy which can be used to pump the Nd:YAG, and is being proposed for the joint USAF/NASA laser communication experiment. Two problems exist. The first is that the low altitude terminal of the laser communications system spends much of its time in darkness making the laser communications system inoperable unless alternative power sources are available on-board. The second is that a steerable parabolic collector is required to collect the sun's energy and focus it on the laser.

(continued on page 4)

8. TECHNICAL PROBLEMS:

Primary problem is currently in development of the array itself. A potential secondary problem has been defined as requirements for long life laser diode arrays. Current life tests have achieved 10,000 hours, equivalent to a one year life. Laser communication systems will require operational lifetimes on the order of 10 years. In discussing with Dr. M. Fitzmaurice (reference 2) he stated that there appears to be no theoretically or analytical reasons to assume that laser diodes will not be capable of 10-year lifetimes. Life tests are currently

(continued on page 4)

9. POTENTIAL ALTERNATIVES:

Alternatives to the laser diode pumping are described in (7) technological options. An alternative to the concept of laser transmission is the use of RF transmission methods. RF limitations are that bulky large arrays and terminals are required; however, they are more feasible than lasers for space to ground because of all weather capability. CO_2 lasers are also a potential alternative, and are pumped by gaseous discharge of the lasing medium.

(continued on page 4)

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

The WPAFB is building laser communications terminals and will use the Nd:YAG laser. No information is available as to whether they are considering laser diode pumping. The AF program is non classified. Contact at WPAFB is Dr. Dale Barry, Technical Director.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

The Nd:YAG operates at 1.06$\mu$and a requirement for low noise, high sensitivity detectors has been defined. GSFC has contracted two approaches to solve the problem using group three-five elements from the periodic table (Indium, Galium, Arsenide, Phosphide). The approaches are:

(continued on page 5)

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 3.1

1. TECHNOLOGY REQUIREMENT (TITLE): Lasers PAGE 3 OF 5

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY -Laser Diode																			
1. Breadboard Dev.					RCA contract with GSFC														
2. Life Testing																			
3. Engineering Model										Presently Scheduled									
										Required Schedule to meet Technology Need Date									
4. Joint AF/NASA communications experiment (Ref. 1)					▼														
5. Testing																			
APPLICATION **																			
1. Design (Ph. C)						NOTE: Technology need date results in minimal design/develop/fab time.													
2. Devl/Fab (Ph. D)																			
3. Operations						** Nd:YAG laser must be available for assembly to laser diode in Ph. C & D.													
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE			▼															
NUMBER OF LAUNCHES						1	1	1					1	1	1			6

14. REFERENCES:

1. NASA Laser Data Relay Link (LDRL) Experiment for the DoD/NASA Cooperative Space Laser Communications Test Flight, Volumes I and II, GSFC, May 1974
2. Technical Discussions between Dr. M. Fitzmaurice, GSFC, and P. R. Fagan, Rockwell International, Nov. 6, 1974, and Dec. 23, 1974.
3. Technical Discussion between Dr. J. McElroy, GSFC, and P. R. Fagan, Rockwell International, Nov. 6, 1974

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RI. 3.1

1. TECHNOLOGY REQUIREMENT (TITLE): Lasers PAGE 4 OF 5

6. Rationale and Analysis - continued

Estimates as of this writing is that the Nd:YAG laser with diode array will be considered ready for use in a space communications system after T-V and vibration testing in the light of unclassified USAF and NASA space communications experiments and programs. Therefore, the laser diode arrays readiness will be derived from a lesser operational model.

7. Technology Options - continued

b. Lamp pumping - Fluorescence and Xenon pumping methods are available; however, their outputs are very broadband and much energy is wasted at wavelengths which do not assist the pumping of the Nd:YAG. Therefore, higher energy is required to maintain the Nd:YAG output.

c. Light emitting diode (LED) pumping - LED pumping has been investigated by RCA and Texas Instruments and have concluded that relative to laser diodes, LED devices are more expensive, have lower power outputs (20 milliwatts), have more cooling problems, and shorter lifetimes.

The use of a laser diode array for pumping has advantages over other pumping techniques. Current options which are under consideration are selection of optimum pumping band, with current preference at 8100 A.

8. Technical Problems - continued

underway at RCA under NASA contract, and at McDonnell Douglas, St. Louis under in-house IR&D.

9. Potential Alternatives - continued

They are capable of very high power output and have been proposed for use in the joint NASA/USAF space communications experiment (reference 1). CO_2 lasers have been used in airborne applications; it is not known if they have been used in spaceborne systems.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RI 3.1

1. TECHNOLOGY REQUIREMENT (TITLE): Lasers PAGE 5 OF 5

11. Related Technology Requirements - continued

a. Phototubes - GSFC has contracted Varian, Palo Alto to develop and prove feasibility of using phototubes with semiconductor targets which are rugged and reliable, efficient, stable, and long life and capable of 5 percent quantum efficiency. They will be available in 18 to 24 months

b. Photodiodes - GSFC has contracted the Rockwell International Science Center to develop group 3-5 photodiodes which are capable of high speed response for high data rate communication systems. Sensitivity will be equal to that of photomultipliers and will be available for the post 1984, one gigabit/sec communications applications.

It should be noted that technology transfer to LIDAR system requirements at Langley Research Center and Johnson Space Center is possible. See RI 4.1 and 4.2.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. RI, 4.1

1. TECHNOLOGY REQUIREMENT (TITLE): Lidar System — PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Systems

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development of space qualified system

4. CURRENT STATE OF ART: Ground to air lidar system for weather analysis at Langley Research Center. Airborne lidar being used by EPA in Nevada for pollution analysis.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

The defined potential lidar techniques are as follows:

a. Measure backscatter from aerosols or Rayleigh phenomena from molecular species which will require a fixed frequency at high power.
b. Differential absorption techniques which require two or three different frequencies, and comparison of absorption at each frequency to determine densities.
c. Exciting molecules at their resonant frequencies and analyzing the light amplitudes and frequency shifts given off to determine composition; this may require a dye laser technique.
d. Measure absorption over a path from a primary satellite to a subsatellite or ground station which will require a dye laser tunable to a specific wavelength of interest.

In discussion with NASA personnel at Langley Research Center and Johnson Space Center primary interest was expressed in (a) and (b) above.

(continued on page 4)

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Lasers are capable of producing coherent, high power, very narrow band energy. Using doubling, tripling, or tuning techniques will permit analysis of atmospheres at absorption or resonant frequencies of interest to the earth scientist.
b. The lidar system would be used with ST-23-S ATL P/L No. 5 (pallet only).
c. JSC is interested in analysis of the backscatter from aerosols or Rayleigh phenomena from molecular species. Backscatter is a function of λ^4 and JSC is particularly interested in UV frequencies at $0.265\,\mu$. LaRC has as its objectives definition of cloud height and its areal extent, penetration of very thin cloud layers, and analysis of earth mixing layers. They feel that attaining a wavelength of $0.53\,\mu$ for analysis of aerosols, molecules, and ozone is adequate.
d. The only laser available which satisfies the lidar system requirements and is space ruggedized is the Nd:YAG laser. The Nd:YAG was developed by WPAFB and a cooperative effort is underway with GSFC to exploit the laser in a space communications system. Laser diode pumping and high sensitivity, low noise solid state detectors for $1.06\,\mu$ are also under development at GSFC (See RI, 3.1). It is likely that the success of the Nd:YAG space experiments will be noted and technology transferred to the lidar system and a lidar model tested in an aircraft environment appears to be adequate to satisfy NASA requirements, however, if a dye laser or other laser is used a level 7 would be required.

TO BE CARRIED TO LEVEL 6/7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RI, 4.1

1. TECHNOLOGY REQUIREMENT(TITLE): Lidar System PAGE 2 OF 4

7. TECHNOLOGY OPTIONS:

a. He:Ne laser
b. Nd:YAG laser
c. CO_2 laser
d. Dye laser
e. Ruby laser

8. TECHNICAL PROBLEMS:

a. He:Ne laser - the He:Ne has been space tested; however, it is not as ruggedized as the Nd:YAG and has too low an output power.
b. Nd:YAG laser - 1/10 joule is off the shelf, with an output power of 1/2 joule breadboarded. The lidar system will require 1 joule output which is theoretically feasible.
c. CO_2 laser - this laser has too long a wavelength to be used for lidar applications, both doubled or tripled.

(continued on page 4)

9. POTENTIAL ALTERNATIVES:

There appears to be no potential alternatives to the laser; however, more firm definition of the wavelengths of interest should be accomplished.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. Dr. Harry S. Melfi (Remote Sensing Branch, EPA, Las Vegas) is currently flying an airborne lidar system for pollution analysis
b. Dr. Pat McCormick (Langley Research Center) is ground testing a 48-inch ruby laser lidar system and a Nd:glass laser for weather analysis.

(continued on page 4)

laser & detectors: 7

EXPECTED UNPERTURBED LEVEL 6

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Laser pointing capability
b. Bore sighted cine camera
c. Bore sighted day/night TV camera
d. JSC feels that the IR band should be explored, but because of attenuation laser outputs on the order of 1 kw should be developed. Also JSC would like to analyze the vacuum UV and requires laser development with an output around 1000 Å.

(continued on page 4)

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 4.1

1. TECHNOLOGY REQUIREMENT (TITLE): Lidar System PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis																			
2. Breadboards (Nd:YAG)																			
3. Life Testing																			
4. Engineering Model/ Test																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

Low noise detectors from GSFC

WPSRB/GSFC Communications Experiment

Dye laser available (not available for LIDAR)

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES						1	1	1		1	1		1	1		1	1	9

14. REFERENCES:

a. Technical discussions among Dr. D. Robbins and Dr. J. Chew, JSC and P. R. Fagan, Rockwell International, October 18, 1974

b. Technical discussions among Dr. M. McCormick and W. Fuller, Langley Research Center and P. R. Fagan, Rockwell International, November 7, 1974

c. Technical discussions between Dr. M. McCormick, Langley Research Center and P. R. Fagan, Rockwell International, January 7, 1975

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G. MATERIAL, COMPONENT, ETC.
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6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. RI. 4.1
1. TECHNOLOGY REQUIREMENT (TITLE): Lidar System	PAGE 4 OF 4

5. Description of Technology - continued

JSC desires to use a Nd:YAG laser with output at 1.06 μ, doubled to 0.53 μ and tripled to 0.265 μ. LaRC is satisfied with the output of 1.06 μ doubled to 0.53 μ.

JSC defines the desired Nd:YAG output as ~1 joule, pulsewidth of 20 nanoseconds, and beam divergence of 2 milliradians, which varies from LaRC requirements only in beam divergence of one milliradian.

8. Technical Problems - continued

d. Dye laser - JSC has defined a potential two-stage dye laser technique using flash lamp pumping. Dye laser state of the art in wavelength generation is 0.25 μ to 1.5 μ with continuous tuning over the full range. A bandwidth of 0.1 Å is available now; however, 0.01 Å bandwidth has been demonstrated in the laboratory. JSC has stated its lidar bandwidth requirement as 10^{-4} Å; therefore, more development of the dye laser is required.

e. Ruby laser - a 48-inch ruby laser doubled to 0.3472 μ is currently being used at LaRC for weather analysis; however, the ruby laser cannot meet the repetition rate of 10 cycles/sec that the Nd:YAG is capable of.

f. Detectors - The Nd:YAG appears to be the primary lidar laser candidate; however, at the 1.06 μ there is high internal noise in amplified solid state silicon diodes. A program is underway at GSFC in developing periodic table group 3-5 detectors with low internal noise at 1.06 μ. See RI, 3.1. Photomultipliers are adequate at shorter wavelengths.

g. Safety requirements will limit laser beam intensity on the ground. The LaRC concept results in a beam intensity on the ground of 8×10^{-10} joules/cm^2, too low to be a hazard.

10. Planned Programs or Unperturbed Technology Advancement - continued

c. Nd:YAG laser diode pumping and low internal noise, high sensitivity detectors responsive at 1.06 μ are under development by Dr. M. Fitzmaurice at GSFC.

d. Nd:YAG laser for communications under development at WPAFB by Dr. Dale Barry, Program Technical Director.

e. Dye laser being built at LaRC for airborne lidar research available 1976

11. Related Technology Requirements - continued

e. Laser pumping techniques using laser diodes are needed and are under development by GSFC.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. RL 4.2

1. TECHNOLOGY REQUIREMENT (TITLE): Nephelometer — PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Systems

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development of a space rated scanning system with active light source.

4. CURRENT STATE OF ART: LED and laser nephelometers breadboarded and some testing for Pioneer Venus 1978 Flyby. JPL has breadboarded a model more specific to requirements herein.

HAS BEEN CARRIED TO LEVEL 4*

5. DESCRIPTION OF TECHNOLOGY

The size and distribution of atmospheric particles can be determined using a detector to observe the sun through a planetary atmosphere. Alternatively, an active source can be used for an in situ measurements. The size and distribution of particles and their complex refractive index are determined from ex... ise of algorithms with detector signal level as primary input.

The minimum particle radius which can be detected is approximately equal to 1 μm.

The detector is moved through an angle on each side of the sun and detector signal intensity is collected. Optimum scan has been determined to be $\lesssim$10 deg. off solar center or a scan of $\lesssim$20 deg. conically. The angular resolution has a major impact upon determination of particle size distribution. (Continued on page 4)

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Selection of active and passive mode and particular source to be used is function of opacity of planets atmosphere.

b. PL-11-A – Pioneer Saturn/Uranus Flyby
   PL-13-A – Pioneer Jupiter Probe
   PL-15-A – Uranus Probe/Neptune Flyby
   PL-22-A – Pioneer Saturn Probe

c. Nephelometer can determine atmosphere particle size, and distribution, and chemical composition.

d. Flight testing required with some results based upon 1978 Pioneer Venus Flyby nephelometer success to derive new capability from lesser model.

* JPL has breadboarded a scanning nephelometer with laser output at 6328 A. No testing accomplished as yet.

TO BE CARRIED TO LEVEL 8

1. TECHNOLOGY REQUIREMENT(TITLE): Nephelometer

7. TECHNOLOGY OPTIONS:

a. Passive system can be used without laser source in atmospheres which are not opaque.

b. Light emitting diodes or lasers can be used for source in opaque atmospheres.

c. System can be mechanically scanned or use CCD's and electronically scan for angular variations. For spectral variations, scanning can be performed using a set of filters (passive instrument), or a set of sources or a tunable laser (active instrument).

8. TECHNICAL PROBLEMS:

a. Software presently available with small study to define implications of planetary atmosphere

b. Effects of high nuclear radiaton on detectors can be handled by shielding if a problem. RI 2.15 discusses radiation effects on semi-conductors. Also, LaRC is

(continued on page 4)

9. POTENTIAL ALTERNATIVES:

None

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

The 1978 Pioneer Venus Flyby will use both and LED and laser nephelometer to investigate Venus atmosphere. Some technology transfer to RI, 4.2 is possible.. The LED nephelometer will be used on the Venus probe. A breadboard model has been built and flight tested by the University of Colorado.

(continued on page 4)

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

Unknown

DEFINITION OF TECHNOLOGY REQUIREMENT NO R1, 4.2

1. TECHNOLOGY REQUIREMENT (TITLE): Nephelometer PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Laboratory Model (Built)																			
2. Construct flight & test models																			
3. Life Testing/ Evaluation																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

NOTE: Present laboratory work funded under JPL Directors Discretionary Funding. Theoretical studies are funded by NASA directly. JPL has requested funding beyond FY 1975.

(Nephelometer development schedule meets technology needs date.)
Ph. C & D schedule can be reduced to total of one year if necessary.

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					▽													
NUMBER OF LAUNCHES						1	1			2		2						6

14 REFERENCES:

1. Discussion among R. Jackson and L. Polaski, NASA-Ames Research Center and E. Kraly, Rockwell International, 15 Nov. 1974
2. Discussion between A. Fymat, Jet Propulsion Laboratories, and P. R. Fagan, Rockwell International, 18 January 1975

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RI, 4.2

1. TECHNOLOGY REQUIREMENT (TITLE): Nephelometer PAGE 4 OF 4

5. Description of Technology - continued

An angular resolution of 15 arc minutes or less has produced the best theoretical and experimental results. Fairly good results can be obtained up to 45 arc minutes, but above 45 arc minutes results are very bad. Scanning can be accomplished either mechanically or electronically using CCD's.

The chemical content is inferred from the refractive index and its spectrum; however, this will require simultaneous detector scanning at two or more different wavelengths. The wavelengths to which the detectors respond are selected on the basis of $\lambda_2 \neq \lambda_1$ where λ_1 is selected to define particle size. The frequency scan can be accomplished using either a set of sources (or filters) or a tunable laser.

The algorithm used is to determine size distribution at λ_1, independent of refractive index and of distribution model, and refractive index spectrum using a set of λ_2's. Additionally by scanning over the 20-degree cone, the horizontal homogeneity of the planet's atmosphere can be determined and maps of size, distribution, and chemical composition made.

A passive nephelometer cannot be used if the atmospheric thickness or composition is such that the sun cannot be seen by the detectors. Therefore, a source of light is needed to activate the detectors. The laser and the light emitting diode, LED can both be used in this application, which is most appropriate to the Earth, Jupiter and Saturn atmospheres. JPL has breadboarded an active scanning model with laser and output at 6328 A.

8. Technical Problems - Continued

b. investigation nuclear radiation effects on CCD's at Langley Research Center.

c. A space rated laser will be required if to be used. Technology transfer of the Nd:YAG laser developed by WPAFB and to be used in RI 3.1 and RI, 4.1 is possible

10. Planned Programs or Unperturbed Technology Advancement - continued

The laser nephelometer is a working breadboard and has not been flown by TRW. It will be used as part of the Venus orbiter model.

The LED has advantages over the laser technique in lower weight and power requirement.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. GE-4.3

1. TECHNOLOGY REQUIREMENT (TITLE): MULTI-FREQUENCY WIDEBAND SYNTHETIC APERTURE RADAR — PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Systems

3. OBJECTIVE/ADVANCEMENT REQUIRED: Provide a three-frequency synthetic aperture radar for space operation.

4. CURRENT STATE OF ART: Synthetic aperture radars are operational in aircraft, but not on spacecraft.

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

(a) Ground resolution requirement is 15 meters (50 ft.); should have variable resolution capability.
(b) Systems will operate in X,K and L bands, 2 polarizations.
(c) High reliability under actual operating conditions.
(d) Swath-widths should be compatible with daily global coverage in meteorological applications.

The need to on-board compensate for the doppler effect due to cross-track velocity component of earth rotation is significant at orbited altitudes. System techniques are not yet developed to accomplish this compensation.

P/L REQUIREMENTS BASED ON: [X] PRE-A, [ ] A, [ ] B, [ ] C/D

6. RATIONALE AND ANALYSIS:

(a) The basis for this radar system requirement is the requirement in the Earth and Ocean Physics and Earth Observation disciplines, for mapping topographic features, geological features, hidden faults, near surface teothermal mapping and oil and mineral resources location.
(b) The specific payload that will utilize this system is OP-02S, "Multi-frequency Radar Land Imagery," and the Meteorological Radar Facility, EO-18A.
(c) Use of synthetic aperture radar from orbital altitudes will afford faster data acquisition and simplified composition of maps of large areas of the globe.
(d) This technological advance will require testing of a simplified system from orbital altitudes. A single frequency system (e.g. 10 GHz) with less stringent resolution capabilities (e.g. 60 meters) will be adequate to test the adequacy of this system.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-4.3

1. TECHNOLOGY REQUIREMENT(TITLE): MULTI-FREQUENCY WIDEBAND SYNTHETIC APERTURE RADAR

7. TECHNOLOGY OPTIONS:

(a) Compensation for cross-track velocity component of earth rotation may be approached through proper programming of the receiver local oscillator, electronic shifting of the beam to the appropriate angle corresponding to the latitude of the sub-satellite point, or through the ground data reduction process.
(b) Use of solid state transmitter/receiver/phase shifter for each antenna array element or group of elements will increase system reliability.
(c) Use of two antennas instead of one for each individual frequency should be explored.
(d) Both pulse-compression techniques and uncompressed techniques should be considered.
(e) Some degree of on-board preprocessing of the radar data should be considered to reduce load on the data link.

8. TECHNICAL PROBLEMS:

(a) SAR requires relatively narrow swath widths, requiring many orbital passes to complete a given large area map.
(b) Wide signal bandwidth complicates recording and transmission.
(c) Individual transmitter/receiver/phase shifter per array element may increase system cost.
(d) A fairly high degree of spacecraft attitude stability is required - both lateral and angular.

9. POTENTIAL ALTERNATIVES:

Optical sensors constitute a potential alternative, however, they do not offer the all weather capability of the radar system.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Expect JPL to request Goodyear to examine feasibility of clutter lock LO to simplify data processing of images involving cross track velocity component. (Clutter lock must operate over water at low sea state conditions). Texas Instrument has development program for solid-state TX/RX/PS module element. Westinghouse & Goodyear proposed 2-frequency SAR for EOS Program. Westinghouse has performed a study of SAR for SEASAT A.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

(a) Techniques of ocean surface truth using aircraft radar.
(b) Wideband transmission and recording.
(c) Precision pointing of phased arrays (e.g. Meteorological Radar requires one milliradian pointing accuracy, Shuttle Imaging Microwave System requires 1.7 milliradar pointing accuracy).

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. GE-4.3

1. TECHNOLOGY REQUIREMENT (TITLE): Multifrequency Wideband Synthetic Aperture Radar — PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Math. modeling																			
2. TX/RS/PS element design																			
3. System model design																			
4. Ground Tests																			
5. Space Tests																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					△													
NUMBER OF LAUNCHES						2	2	2	2	1	1	1	2	2	2	1	1	19

14. REFERENCES:

1) GE-Utica Study or X-Band phased array with element modules.

2) Final Report - Spaceborne Syntheic Aperture Radar Pilot Study
4/11/74
Contract NAS5-21951
for GSFC
by Westinghouse Electric Corp.
Systems Development Div.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. GE-4.4

1. TECHNOLOGY REQUIREMENT (TITLE): Wave Height Altimeter — PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Systems

3. OBJECTIVE/ADVANCEMENT REQUIRED: Obtain ocean wave height measurement with precision of 0.5 meters or 10% (Min Wave 1M - Max Wave 20M)
(25% min. wave height of 2M)

4. CURRENT STATE OF ART: Designs for GEOS-C and ATS-F have 2 to 3 meter precision as a goal (see Ref. 1); Skylab approximate precision of 1.5 to 2 meters.

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

(a) Earth and Ocean Physics investigations of wave height requires precision of 0.5 meter or better.
(b) All weather capability for measuring wave heights; include effects of normal rainfall and corrections for water vapor.
(c) Skylab wave height measurements are being evaluated; state-of-the-art approximately 1.5 to 2 meters precision.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) Present goal for topography, Sea Sat A, is 0.1 meter. Wave height precision must be less stringent due to difficulty in measuring with short integration time and large signal amplitude fluctuations; goal set at better than 0.5 meters precision or ±10% Parameter of interest is wave height distribution (see reference 3)
(b) Seasat B (OP-07-A) is the principal beneficiary of this technological advancement.
(c) Information effectively usable by Coast Guard, Corp of Engineers, Off-Shore Nuclear Power Stations, general shipping.
(d) Aircraft test at high altitude will be required in the proposed technology development to determine weather effects as well as assessing performance parameters.

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TO BE CARRIED TO LEVEL 6

1. TECHNOLOGY REQUIREMENT(TITLE): Wave Height Altimeter

7. TECHNOLOGY OPTIONS:

(a) Short Pulse Altimeter Approach - extensions of current short pulse systems; achieve higher precision by using higher prf with higher peak power and shorter pulses, narrower beam with accurate nadir pointing, and more extensive signal processing to reduce error due to pulse and pulse amplitude fluctuations. These will all increase weight and costs to achieve the higher level of performance.

(b) Long Pulse Scatterometer - uses averaging of signals by long pulses (milli-seconds); further extensive investigations would be required to extract high precision wave height data; would be lower power than short pulse system in (a) above.

8. TECHNICAL PROBLEMS:

(a) Short Pulse Altimeter - serious jitter in sample/hold circuit is due to large fluctuation of signal amplitude; use of higher pulse repetition frequency than in current systems is suggested to prevent this, at cost of shorter pulses, higher peak power, and narrower beam antenna with nadir pointing more critical; signal processing becomes more extensive, possibly incorporating very wide band recording.

--Continued--

9. POTENTIAL ALTERNATIVES:

Dual Frequency Scatterometer (ref. 2) requires further considerations, concept restricted to aircraft use.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

SeaSat A will provide SeaSat B Technology Development.
On Board processing study done by technology surveys under AAFE now underway
Houston Workshop recommended 2 to 5 cm for topographic applications, possibly utilizing a phase measuring scheme.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

Tube Development: (a) for short pulse system, higher peak power, higher duty cycle, shorter pulses
(b) long pulse operation (1 to 4 msec) with 50% duty cycle.

Antenna Pointing Control: accurate nadir pointing.

Energy Storage: for short pulse configuration, energy storage to provide 2 to 3 times available power level for ten seconds.

(continued)

1. TECHNOLOGY REQUIREMENT (TITLE): Wave Height Altimeter

8. TECHNICAL PROBLEMS (Continued)

(b) Effects of adverse weather conditions on the measurements.
(c) Tube development and/or modifications required.
(d) Precise orbit determination required for topography.
(e) Use of solid status X mitters secondary now-good for shuttle increase reliability, reduce power consumption

11. RELATED TECHNOLOGY REQUIREMENTS

On board data processing techniques may be employed to reduce raw data transmission/ground processing and to provide real-time data on sea-state.

The development of solid state transmitters will permit their utilization in this application, to increase reliability, reduce power consumption.

Digital pulse compression might provide a more flexible means of adapting the system when optimizing for Sea-state and altitude measurements.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. GE 4.4

1. TECHNOLOGY REQUIREMENT (TITLE): Wave Height Altimeter PAGE 4 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analyses	—	- -	- -																
2. Ground Tests	—	- -	-																
3. Model Design, Fab.		—	—																
4. Aircraft Tests			—	—															
5.																			
APPLICATION																			
1. Design (Ph. C)					—	—													
2. Devl/Fab (Ph. D)						—	—	—											
3. Operations								—	—	—	—	—	—						
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE				△														
NUMBER OF LAUNCHES								1										1

14 REFERENCES:

1. "The Space Applications Program 1974", NASA Office of Publications, Section 4.

2. Weissman, David E., "Two Frequency Radar Interferometry Applied to the Measurement of Ocean Wave Height", IEEE Transactions on Antennas and Propagation, September 1973, pages 649 - 656.

3. Walsh, Edward J., "Analysis of NRL Radar Altimeter Data", Radio Science, Vol. 9, #8-9, pp 711-722, Aug - Sept. 1974

4. McGoogan, J. T., "Precision Satellite Altimetry".

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. GE 4.5

1. TECHNOLOGY REQUIREMENT (TITLE): TRANSMITTER/COUPLER SYSTEM — PAGE 1 OF 5

2. TECHNOLOGY CATEGORY: SYSTEM, R.F.

3. OBJECTIVE/ADVANCEMENT REQUIRED: HIGH POWER TRANSMISSION THROUGH DIPOLE ANTENNAS THAT ARE MUCH SHORTER THAN ONE WAVELENGTH

4. CURRENT STATE OF ART: HAVE FLOWN AIRCRAFT AND SPACECRAFT WITH ANTENNAS THAT ARE SHORT RELATIVE TO TRANSMITTED WAVELENGTH. POWER LEVELS USED WERE LOW COMPARED WITH THE SUBJECT REQUIREMENTS. HAS BEEN CARRIED TO LEVEL 5.

5. DESCRIPTION OF TECHNOLOGY

The requirements for transmission through the specified 330 meter long dipole antenna are as follows:

POWER LEVEL	FREQUENCY RANGE	WAVELENGTH (M)	ANTENNA L./WAVELENGTH
1 KW	300 Hz to 0.2 MHz	10^6 to 1500	0.00033 to .22
10 KW	0.2 MHz to 2.0 MHz	1500 to 150	0.2 to 2.2
10 KW	2.0 MHz to 20.0 MHz	150 to 15	2.2 to 20.2

Automatic antenna tuning devices for application to antenna length/wavelength ratios down to 0.0003, and power levels up to 10 KW need to be developed. The present state of the art is exemplified by H.F. antenna installations on 707 type aircraft. Operation is in the 2-30 MHz region, and the antenna is a 9' boom mounted near the tip of the vertical stabilizer. This works against the aircraft fuselage to form an asymmetrically fed dipole. The reactance characteristics are determined by the short portion (boom), leading to high cap-

(CONTINUED ON NEXT PAGE)

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(A) The R.F. frequencies and power levels listed in (5) above are those that are specified to induce the plasma excitation and generation of plasmic waves required by the Atmospheric and Space Physics Experiment. (See attached rationale description).

(B) The benefitting payload is AP-06S "Atmospheric, Magnetospheric Plasmas in Space" (AMPS).

(C) The development of adequate tuning devices for the antenna is essential to the ability to transmit the required power levels and to the prevention of system electrical breakdown.

(D) Due to the difficulty of physically simulating the pertinent characteristics of the space environment, it is recommended that a simplified space test of a scaled-down model be conducted. This may involve a brief test on one of the Arobee rocket flights.

TO BE CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY (Continued)

ac.tive reactances. Impedance matching is accomplished by an automatic tuner, located in the stabilizer, which senses the mismatch and drives it out. All components are designed for minimum loss and relatively good efficiencies are realized. The transmitter powe is 50 watts, and voltage breakdown is not a problem.

The Alouette-2 satellite topside sounder operates in a wider frequency band. The sounder sweeps from 0.2 to 14.0 MHz once every 30 seconds. It provides an average pulse power of 300 watts at a PRF of 30 cycles per second and a pulse width of 100 sec. The apogee and perigee of the satellite are 2982 km and 502 km, respectively.

6. RATIONALE AND ANALYSIS: (Continued)

(A) Antenna properties are determined by their dimensions in wavelengths. When these are very small, the impedance and power handling properties become limiting factors.

For instance, one of the antennas under consideration is a dipole 330 meters in length, required to operate under the extreme conditions of:

1. Frequency 300 Hz
2. Power 1 KW

At this frequency the wavelength is 10^6 meters, and the dipole is 0.00033 wavelengths long. The radiation resistance is 0.002 ohms. The reactance depends upon the conductor diameter; but in any event is several thousand ohms capacitive. The significance of these numbers may be appreciated by considering that, for reasonable power transfer from the transmitter to free space via the antenna the latter must have impedance properties comparable to the transmitter. This is in the order of $50 + > j0$ ohms; the tremendous disparity requires a tuning device which matches the impedances.

The ohmic losses in the antenna and tuning device will be large in comparison to the radiation resistance. Since the efficiency of the system is given by the ratio of radiation resistance to total resistance, the radiated power will be only a fraction of one percent of the total available. The rest is dissipated as heat. Moreover the system Q, representing the ratio of stored energy to energy dissipated is extremely large which means that the bandwidth is extremely narrow. This will be affected by the impedance change resulting from ionized sheaths which may form about the antenna due to a potential difference between it and any neutral plasma. The sheath structure depends upon antenna voltage, orientation, velocity and the temperature of the ambient electrons and ions.

Extremely high voltages will appear in the tuning system, due to its high Q, for moderate powers.

In the event that all of the power could be transferred to the dipole, another voltage problem may arise. The periodic charge accumulation at the dipole tips is very large, being limited only by the small capacity of the tips. Thus, in the presence of an ionized medium, such as a plasma, voltage breakdown may occur.

In any case, the current flow must be balanced in order that the dipole radiation pattern may be realized without degradation. This is readily accomplished by connecting the dipole to the transmitter by a balun. This is a simple network which goes from terminals which are balanced to ground (dipole) to unbalanced terminals (transmitter).

In order to place the problems mentioned above in perspective it is instructive to consider the ideal case, in which the dipole would be one-half wave long. The radiation resistance in that ideal case is 73 ohms, and the reactance is 43 ohms inductive. This may readily be matched to the transmitter with essentially 100% efficiency. For the 330 meter dipole, the corresponding frequency is 0.455 MHz; here the specified power is 10 K.W. The potential gradient at the dipole tips is then 2800 volts per centimeter, assuming the use of #4 wire. For orbits in the 200-300 N.M. range the pressure is sufficiently low that voltage breakdown may not be a problem.

At the upper end of the specified frequency band, 20 MHz, the dipole is 22 λ long. This produces a multilobed pattern, and high impedance values which again bring up the problem of realizing a satisfactory match to the transmitter.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE 4.5

1. TECHNOLOGY REQUIREMENT(TITLE): TRANSMITTER/COUPLER SYSTEM PAGE 4 OF 5

7. TECHNOLOGY OPTIONS:

The proposed technology advancement will consider the following aspects: (a) voltage breakdown at various frequency, power levels and environmental plasma models; (b) various techniques for automatic tuning of the antenna; (c) radiation pattern at the dipole; and (d) impedance change resulting from ionized sheaths.

8. TECHNICAL PROBLEMS:

The large impedance mis-match between the antenna and the transmitter, due to the short antenna is comparison with the wavelength, would cause very inefficient radiation characteristics. The tuner to be developed would have to be designed to minimize the losses.

Electrical arcing between antenna and transmitter is a possibility.

9. POTENTIAL ALTERNATIVES:

Two or more antennas could be used to cover the entire frequency range of interest. At the low frequencies (300 to 200,000 Hz), antenna lengths in the order of kilometers could be employed to effect better matching.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

AMPS Program

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

The structural aspects of long dipole antennas and their deployment should be investigated.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. GE 4.5

1. TECHNOLOGY REQUIREMENT (TITLE): Transmitter/Coupler System PAGE 5 OF 5

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Circuit Analysis																			
2. Math. Simulation																			
3. Model Design																			
4. Model Tests (Ground)																			
5. Model Test (Rocket)																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					Δ													
NUMBER OF LAUNCHES							1	1	1	3	3	4	3	4	3	4	3	30

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-5.1

1. TECHNOLOGY REQUIREMENT (TITLE): Levitation Unit PAGE 1 OF 5

2. TECHNOLOGY CATEGORY: Special Devices

3. OBJECTIVE/ADVANCEMENT REQUIRED: Provide position and temperature control to a large spectrum of materials and specimen sizes while in a levitated state in micro-gravity, and provide adequate heat rejection.

4. CURRENT STATE OF ART: A limited number of experiments have been performed in drop towers, electromagnetic levitation in 1g field, and acoustic levitation in 1g field. HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

Space processing requirements are characterized by the following approximate ranges:

(a) Sample volume requirements for the various materials and products are shown on Table 5-a-1.
(b) Correction for translational acceleration: 10^{-4} G.
(c) Material Resistivity: 10^{-8} to 10^{-2} ohm-meter (electromagnetic levitation)
10^{-2} - 1 ohm-meter (acoustic levitation)
(d) Melting Temperature of Metals: 312°K (Rubidium) to 3660°K (Tungsten)
(e) Heat dissipation from metallurgical processes up to 20-30 KW.

P/L REQUIREMENTS BASED ON: [X] PRE-A, [ ] A, [ ] B, [ ] C/D

6. RATIONALE AND ANALYSIS:

(a) Technology advances in specimen positioning and heating during levitation processing are needed to permit efficient application of zero-G and other unique properties of the space environment. The material types, quantity and other parameters indicated in item 5 above were chosen to represent a large segment of the potential early-operational processing requirements, which will be tested and demonstrated on Spacelab. The acceleration correction requirement is based on the extent of perturbation due to astronaut motion.

Analyses and experiments to date show that most of the stated requirements can be met by means of electromagnetic or acoustic positioning systems. The former is required for materials requiring a vacuum or ultra-pure gas environment during processing, provides rapid heating by electromagnetic induction or by means of an electron beam but is restricted to materials whose resistivity does not exceed 10^{-2} ohm-meters when heated. For higher resistivities, acoustic positioning with radiant heating can be considered.

--Continued--

TO BE CARRIED TO LEVEL 5

Table 5(a)-1. Experimental Process Material Size Requirements

Material	Sample Size	Processed Product (Typ.)
Metal Oxide Glasses	0.5 cm (sphere radius)	Glass Boules
Berillium & Beryllia	1.0 cm (sphere radius)	Uniformly Dispersed Ingot
Tungsten	0.5 cm (sphere radius)	Fine Grained Spheroids
Nickel + Tungsten	0.5 cm (sphere radius)	Eutectic W/N_i
Molybdenum	0.5 cm (sphere radius)	Fine Grained Spheroid
Tantalum or Niobium Alloys	0.5 cm (sphere radius)	Fine Grained Spheroid or Single Crystals
Crystalline Ge Te	1 cm (sphere radius)	Chalcogenide Glass
Copper + Tungsten	0.5 cm (sphere radius)	Uniformly Distributed Spheroids
Titanium, Lanthanum Oxide	0.5 cm (sphere radius)	Uniformly Distributed Ingot
High Silicates & Silver Chloride	4 cm (sphere radius)	Uniformly Distributed Boule
Iron Antimonide & Indium Antimonide	4 cm (sphere radius)	Eutectic Boule
Niobium & Tin	2 cm (sphere radius)	Monotectic Boule
Lanthanum Hexaboride	2 cm (sphere radius)	Polycrystalline Boule
Molybdenum Disilicide	2 cm (sphere radius)	Polycrystalline Boule
Silicate Glass + Europium and/or Cerium	2 cm (sphere radius)	Amorphous S_iO_2 Glass and Dispersed Europium, Cerium
Crystalline Palladium Silicon	2 cm (sphere radius)	Amorphous Palladium Silicon
Iron/Iron-Sulphide Composite	2 cm (sphere radius)	Lamellar Fe-FeS

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-5.1

1. TECHNOLOGY REQUIREMENT (TITLE): Levitation Unit PAGE 3 OF 5

5. DESCRIPTION OF TECHNOLOGY: (cont'd)

Current state of the art may be typified by experiments in free-fall towers, with samples in the order of 1-5 cc; electromagnetic levitation of 10 gm of molten tungsten (GE Space Division); and acoustic levitation experiments using 0.3 gram specimens in 1g field.

6. RATIONALE AND ANALYSIS: (cont'd)

(b) The technology advancement will benefit the following payloads:
SP-13S - SPA No. 13 - Automated Levitation
SP-14S - SPA No. 14 - Manned and Automated S.P.A.
SP-15S - SPA No. 15 - Automated Furnace/Levitation

(c) The determination of optimum techniques as indicated above will greatly accelerate the advent of operational space processing facilities for the benefit of mankind.

(d) This state of the art advancement must be carried to the breadboard stage and tested in a simulated space environment.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-5.1

1. TECHNOLOGY REQUIREMENT(TITLE): Levitation Unit PAGE 4 OF 5

7. TECHNOLOGY OPTIONS:

The following optional techniques must be investigated, relative to the required material and processes:

Positioning

(a) Electromagnetic - limited to resistivities below 1/100 ohm-meter
(b) Acoustic - must utilize a gas medium of significant pressure
(c) Electrostatic

Heating

(a) RF induction - uses eddy current effect, skin depth is a function of field coupling and frequency.
(b) Electron Beam - must consider secondary electron emission and optimum electron primary energy level.
(c) Solar Furnace Heating - requires large collector and focussing device.
(d) Arc imaging.

8. TECHNICAL PROBLEMS:

Special problems to be considered are as follows:

(a) Formation of bubbles in liquid specimens (may require specimen rotation about its axis)
(b) Degree of stirring due to positioning fields.

9. POTENTIAL ALTERNATIVES:

Levitation in a one-G field may be feasible in some limited applications.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

(a) Payload Definition and Payload Equipment Study (MSFC)
(b) SPA Kit Study (Power and Heat Rejection Kit) (MSFC)

The unperturbed technology advancement would consist of demonstration of individual components.

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

Due to the large energy requirements in many of the metallurgical and glass processes, the development of suitable power supplies (to supplement the Spacelab power) and attendant heat dissipation provisions are critical to the attainment of the desired goals.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. GE-5.1

1. TECHNOLOGY REQUIREMENT (TITLE): Levitation Unit PAGE 5 OF 5

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analytical Studies																			
2. One-G Tests																			
3. Drop Tests (Zero-G)																			
4. Sounding Rocket Equipment Development																			
5. Breadboard Design																			
6. Breadboard Tests																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				△														
NUMBER OF LAUNCHES						1	1	2	2	2	2	2	2	2	2	2	2	22

14. REFERENCES:

(a) "Electromagnetic Containerless Processing Requirements and Recommended Facility Concept and Capabilities for Spacelab," Final Report, Contract No. NAS-8-29680 (General Electric Co.).

(b) "Design Analysis of Levitation Facility for Space Processing Applications", Final Report, Modification No. 3 to Contract No. NAS-8-29680 (General Electric Co.).

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE 5.2

1. TECHNOLOGY REQUIREMENT (TITLE): Continuous Flow Electrophoretic Column/Fractional Collecting System

2. TECHNOLOGY CATEGORY: Special Devices

3. OBJECTIVE/ADVANCEMENT REQUIRED: Provide fluid handling techniques to enable purification of biologicals to purity 5-10 times better than earth-based processes.

4. CURRENT STATE OF ART: Initial zero-G tests on Apollo show the feasibility of attaining improvements in purity through electrophoresis, however, significant advancements are required to make this a viable processing technique.

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

The basic parameters for this system are as follows:

Total Sample Volume: 10 cc
Total Column Volume: 10 cc
Buffer Pump Rate: 30 cc/min. (max.)
Temperature Control: 263^{o}K to 278^{o}K
Voltage Gradient: 100 V/CM (max.)
Current Density: 100 milliamp/sq. cm
Pump Pressure Fluctuations: less than $\pm$10 N/sq. meter

The technology for meeting the above parameters is available; however, the desired high purity may not be attainable due to wall contamination in the electrophoretic cell, which causes degrading changes in the cell characteristics.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) Increased electrophoretic cell thickness possible in zero-G makes theoretical separation resolutions 5 to 10 times better than those on ground based systems. However, wall contamination seriously degrades the reproducibility of the cell characteristics, thus adversely affecting the purities that can be attained. A large portion of the contamination may be traced to fuel handling functions such as (biological) sample insertions wherein contact of the sample with the cell walls occurs very often with the state-of-the-art techniques.

(b) The benefitting payloads are SP-14S (SPA No. 14, Manned and Automated), and SP-01S (SPA No. 1, Biological - Manned).

(c) Reductions in contamination will benefit both ground based and space based electrophoretic processes, removing a significant obstacle to the attainment of higher purity biologicals.

(d) This technology program should be carried to the point where an experimental system is tested and demonstrated in the laboratory (in one-G). Zero-G effects should be projected and appropriate technique adjustments made to permit satisfactory operation in space.

TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-5.2

1. TECHNOLOGY REQUIREMENT(TITLE): Continuous Flow Electrophoretic Column PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

Various aspects to be considered in the technological advancement are:

(a) Attainment of high degree of cleanliness in the equipment and facility
(b) Proper sample insertion techniques
(c) Avoidance of batch-to-batch contamination
(d) Prevention of bubble formation in the cell
(e) Maintenance of sample away from the cell walls (e.g., through the use of externally applied electrostatic forces)

8. TECHNICAL PROBLEMS:

It is anticipated that significant amount of contaminants will tend to deposit on the cell walls, regardless of the precautions. The main problem is to avoid not only excessive contamination but also uneven distribution from one cell wall to the other, and changing conditions with respect to time.

Suppression of electro-osmosis is a technological problem. Bonded charges along the container surfaces interact with the electrolyte, affecting yield.

9. POTENTIAL ALTERNATIVES:

Many types of separation processes exist and are undergoing technological improvements (e.g., chromatography, centrifugation, etc.). Each type of process is applicable to a limited set of applications; there is no known alternative method to electrophoresis.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

The unperturbed level of technology advancement is estimated to reach the testing of theories through physical experimentation in the laboratory.

EXPECTED UNPERTURBED LEVEL 3

11. RELATED TECHNOLOGY REQUIREMENTS:

(a) Investigations of optimum cell-wall coatings
(b) Development of multi-electrode-pairs (Beckman)

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE 5.2

1. TECHNOLOGY REQUIREMENT (TITLE): Continuous Flow Electrophoretic Column PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis																			
2. Experiments on Techniques																			
3. Model Fabrication																			
4. Model Testing																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					△													
NUMBER OF LAUNCHES						1	1	2	1	1	1	1	1	1	1	1	1	13

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RL 5.3

1. TECHNOLOGY REQUIREMENT (TITLE): Package, Solids Analysis

2. TECHNOLOGY CATEGORY: Special Devices

3. OBJECTIVE/ADVANCEMENT REQUIRED: Analysis of chemical content of Encke tail

4. CURRENT STATE OF ART: Breadboard of workable model developed at GSFC

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Two major efforts have been carried out in recent years on the development of mass-spectrometric techniques for the compositional analysis of micrometeoroid material from spacecraft. The first of these (headed by H. Fechtig and E. Grün of the Max Planck Institut fur Kernphysik, Heidelberg, Germany) has been successfully flown on the Helios Solar Probe. The second effort was under the leadership of J. F. Friichtenicht of TRW, Redondo Beach, California. The two approaches are identical in concept: a compositional analysis of micrometeoroid material is made through a time-of-flight (TOF) mass spectrometer analysis of the plasma generated when a small dust particle strikes a tungsten target at high velocity. Information on the size of the particle is gained through a measurement of the total integrated plasma charge and a measure of the relative particle velocity is made through the measurement of the rise time of the plasma "pulse".

(continued on page 4)

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. The most widely accepted theory of cometary origin assumes comets to be made up of the primordial "stuff" of the solar system. If so, cometary solids and small asteroids may be the only sources of undifferentiated, unmixed primitive material available, and the elemental (and isotopic) composition of this material is of fundamental importance in geochemistry and cosmogeny. If not of solar system origin, the cometary solids must come from interstellar space, and an analysis of interstellar material is no less interesting.

b. The best way to measure the composition of the non-volatile fraction of the cometary nucleus during a flyby is probably to analyze the composition of the cometary dust reaching the spacecraft.

c. PL-18-A Encke Rendezvous and PL-19-A Halley Comet Flyby are benefiting payloads.

d. Model must be constructed with improved plasma generating particle target and subjected to testing in the space environment.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RI, 5.3

1. TECHNOLOGY REQUIREMENT(TITLE): PAGE 2 OF 5

Package, Solids Analysis

7. TECHNOLOGY OPTIONS:

Lesser capability models by:

a. H. Fechtig, Max Planck Institute, Germany (Helios)

b. J. F. Friichtenicht, TRW

c. Dr. S. Auer, GSFC device with SiO target

8. TECHNICAL PROBLEMS:

a. A redesign of the target to materials which are not likely associated with comet composition is desirable. Presently Si and SiO_2 compounds are used for the target and it is desirable they be switched to materials such as germanium.

9. POTENTIAL ALTERNATIVES:

None known

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

None known or anticipated

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

Unknown

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. R1, 5.3

1. TECHNOLOGY REQUIREMENT (TITLE): Package, Solids Analysis

PAGE 3 OF 5

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Breadboard completed 10/74						NOTE: No present funding													
2. Develop new target																			
3. Construct model																			
4. Life Testing																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE				▽														
NUMBER OF LAUNCHES							1				1							2

14 REFERENCES:

a. Science Aspects of a 1980 Flyby of Comet Encke with a Pioneer Spacecraft, L. D. Jaffe, et al; 760-96, May 20, 1974, JPL
b. Cosmic Dust Analyzer, Final Report, 10735-6002-RO-00, TRW Systems Group, Redondo Beach, Calif., 1971
c. Letter from J. F. Friichtenicht, TRW to H. Ikerd, GDCA, December 26, 1974
d. Discussion between C. Giffin, Jet Propulsion Laboratory, and P. R. Fagan, Rockwell International, January 22, 1975
e. Discussion between Dr. S. Auer, GSFC, and P. R. Fagan, Rockwell International, January 24, 1975.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RI. 5.3

1. TECHNOLOGY REQUIREMENT (TITLE): Package, Solids Analysis

5. Description of Technology - continued

The TOF mass spectrometer analysis assumes that the ionic composition of the impact-generated plasma is directly related to the bulk composition of the micrometeoroid (or in this case the cometary dust particle). By accelerating the plasma ions through a potential difference, and then letting them pass along a field-free drift region of known length, the atomic masses of the ions can be determined by their respective arrival times at a detector.

A simplified schematic of the instrument is shown in Figure 1, page 5. Upon impact of a dust particle on the target, a plasma is generated, the time profile and intensity of which is measured. The plasma-detection amplifier sends a signal to the signal-conditioning electronics which starts a clock for timing the arrival times of ion "bunches" as they reach the resolved ion detector. The signal-conditioning electronics format the measurement of the integrated charge in each ion "bunch" and time-label it for mass identification.

Dr. S. Auer of GSFC is the inventor of the analyzer used on the Helios Solar Probe and has further improved the analyzer by incorporating two important improvements. The Helios analyzer was limited in its ability to detect a wide range of atomic mass units as it could only focus on a given single AMV and respond to a narrow AMV bandwidth centered around the selected single AMV value.

Dr. Auer developed and demonstrated a static focus technique which increases the response to an AMV range of 1-300 AMV. The target was changed to a capacitor which when struck by a particle had a capacitance discharge. This improved ionization efficiency, particularly for slow moving particles.

The linear particle path length was changed to a circular path, improving the path length the particle can travel.

The most important improvement was to change the tungsten (or gold in some concepts) target to a thin film capacitor which is charged by applying 30-60 V between the two conductors. The thicker substrate is positive relative to the thinner conductor.

The technique was formerly used in space to detect micrometeoroid impact and developed for Explorer 46 by LaRC. When a particle enters the field between the two conductors a spark is generated. The ions are extracted from the spark and the ion current has been found to be 7 orders of magnitude better than that generated by Helios. The resultant is higher resolution, wider AMV response than the Helios Analyzer, and ability to detect slow moving particles on the order of 10 m/sec.

1. TECHNOLOGY REQUIREMENT (TITLE): Package, Solids Analysis

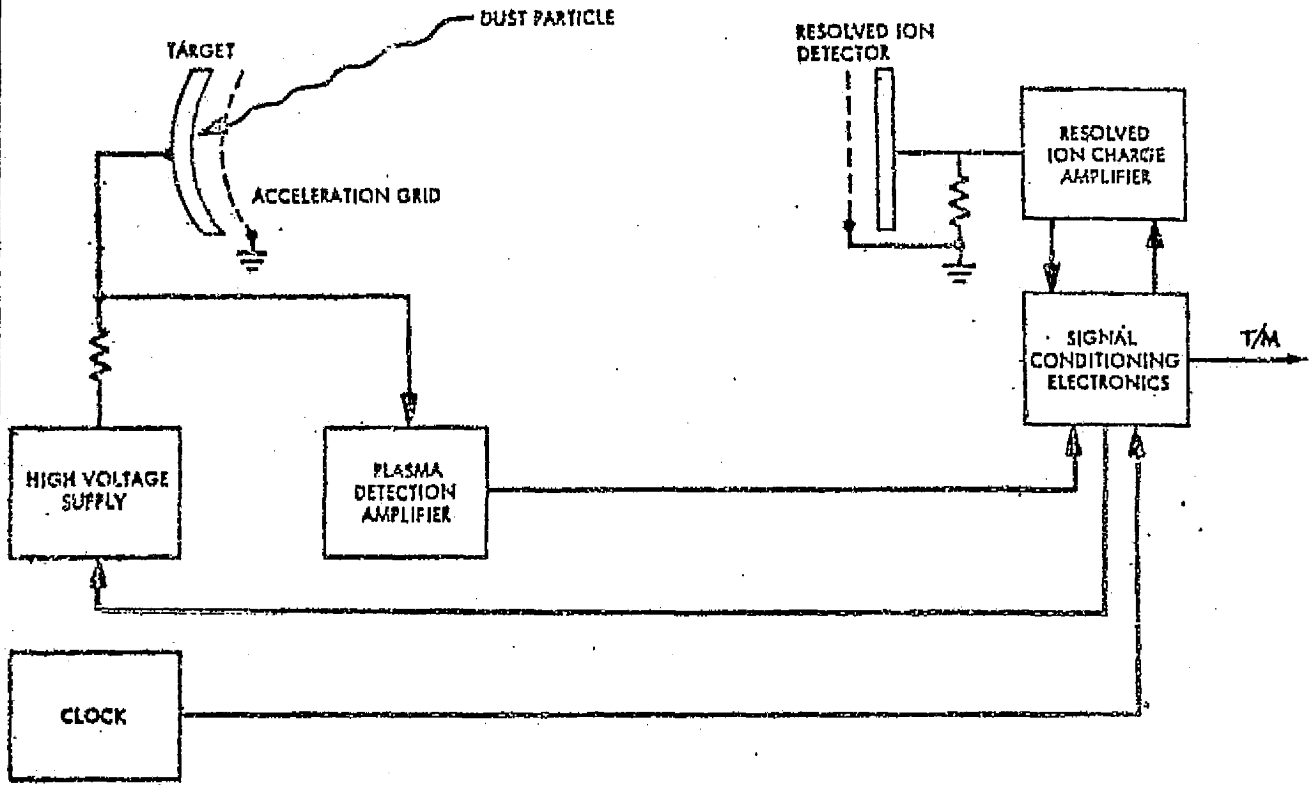

Figure 1. Simplified block diagram: Cometary Dust Analyzer

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-5.4

1. TECHNOLOGY REQUIREMENT (TITLE): High Power, High Efficiency Transmitter PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Special Devices

3. OBJECTIVE/ADVANCEMENT REQUIRED: Obtain power output in the range of 50 to 500 watts in the frequency band 620 to 790 MHz, transmitter characteristics to be: 45% efficiency, 30 dB gain, 20 MHz bandwidth, minimum size and weight.

4. CURRENT STATE OF ART: 100W, 45% efficiency, 30MHz bandwidth, single channel centered at 790MHz.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Direct broadcast CW operation, single channel operation such as required for the Disaster Warning Satellite (CN-54A).

Critical parameters are: power output, efficiency, size, weight, and long life.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) Low cost ground receiver in a building (15 dB building attenuation); 58.6 dBW EIRP required for a 9.0 dB S/N ratio at the receiver; receiver noise temperature of 1100°K.
(b) Benefitting payload: CN-54A, Disaster Warning Satellite.
(c) Solid-state devices and circuits increase lifetime, reliability of transmitter and offer opportunity to minimize size and weight of transmitter.
(d) The technology program should culminate in the testing of a breadboard model on ground tests.

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TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-5.4

1. TECHNOLOGY REQUIREMENT(TITLE): High Power, High Efficiency Transmitter PAGE 2 OF 4

7. TECHNOLOGY OPTIONS:

Critical factors in the Disaster Warning System that affect the transmitter output power and satellite payload use:

(a) Efficiency of the transmitter affects the DC power requirements for the transmitter (linear relationship).
(b) Noise temperature of the ground receiver affects the required power output of the satellite transmitter (direct relationship in dB).
(c) Building attenuation directly affects the required transmitter output power (direct relationship in dB); antenna location outside the building desirable.
(d) Number of simultaneous signals in the transmitter affects the output power available (limited by intermodulation signal level requirements); design assumed to be one carrier per transmitter. (Approximately 6 dB back-off from maximum power output is required for 2 simultaneous signals.)

(continued)

8. TECHNICAL PROBLEMS:

State-of-the-art in solid-state transmitters is: power up to 100W, 45% efficiency, 20 MHz BW. In the power range of 100W to 430W, technical problems are: (1) thermal problems (transistor junction temperature = 125°C maximum); (2) large size and weight of the transmitter; (3) efficiency (loss of efficiency due to combining losses).

9. POTENTIAL ALTERNATIVES:

Cross-field amplifier can be used for higher power outputs; development of amplifier is required; cathode life appears to be a limiting factor in long life operation (5-7 years).

The use of an outside antenna would reduce the attenuation from the present 15 dB specification, thus lowering the transmitter power requirement. Cost of user receiver systems would increase.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Global Positioning Satellite Program - 1600 MHz transmitter being developed by North American Rockwell.

GE in-house program - VHF and 1600 MHz transmitters.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

None

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-5.4

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 3 OF 4

HIGH POWER, HIGH EFFICIENTY TRANSMITTER

7. TECHNOLOGY OPTIONS: (Continued)

(e) Power output per transmitter affects the size and weight of the payload; the number of transmitters affects the size and weight of the payload.

(f) Receiver bandwidth directly affects C/N of the receiver and thus the rf power output and DC power input requirements of the transmitter.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. GE-5.4

1. TECHNOLOGY REQUIREMENT (TITLE): High Power, High Efficiency Transmitter — PAGE 4 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE: High Power Amplifier (100-430W)

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Systems Tradeoffs																			
2. Transistor Selection																			
3. Thermal Design																			
4. Ampl. Ckt. Design																			
5. Breadboard Test																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				△														
NUMBER OF LAUNCHES							1	1			1					1		4

14. REFERENCES:

(a) Telephone conversation with J. R. Ramler, NASA Lewis.
(b) Feasibility Study of Using Satellites for a Disaster Warning System, R-3015-2-1.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-5.7

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 4

Self aligning Multipin Electrical Connector Assembly

2. TECHNOLOGY CATEGORY: Special Devices

3. OBJECTIVE/ADVANCEMENT REQUIRED: Electrical interface for resupply and refurbishment of orbiting spacecraft

4. CURRENT STATE OF ART: Development hardware has been fabricated, feasibility of concepts has been demonstrated

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Multipin electrical connectors are required to transverse the spacecraft/module interface of an in-orbit serviceable spacecraft. Connector design will permit reliable engagement or interruption of power, data, and communication lines when malfunctioning and/or depleted systems are replaced remotely on the orbiter.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) The present method for orbiting a spacecraft precludes its recovery for repair and/or refurbishment. The cost effective solution is to provide a shuttle compatible system to recover, repair, and reorbit spacecraft.

(b) EOS*-A, B, C, and D; SMM; EGRET; SSOS; SEOS; SeaSAT** will benefit. BESS is potentially a benefiting payload.

(c) In orbit repair and/or refurbishment of spacecraft will replace the present method of operation, i.e., launching a second or backup spacecraft to complete the mission of the malfunctioning spacecraft.

(d) The test of a model in a spacecraft (EGRET) to demonstrate its applicability will satisfy this technology requirement.

*EO-08A

**OP-07-A & 09A

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-5.7

1. TECHNOLOGY REQUIREMENT(TITLE): Self Aligning Multipin Electrical Connector Assembly

7. TECHNOLOGY OPTIONS:

(a) Develop a connector component for refurbishment and/or repair of malfunctioning spacecraft system as described above in paragraph 5.

(b) Capture and return spacecraft to earth for electrical disconnect.

(c) Continue present mode of operation, i.e., launch a backup spacecraft to replace the one that has malfunctioned.

8. TECHNICAL PROBLEMS:

(a) Alignment and mating of up to 200 power, data and communication pins and sockets including an undetermined number of coaxial interfaces.

(b) The effect of thermal gradients on the alignment of pins and sockets.

(continued on next page)

9. POTENTIAL ALTERNATIVES:

There are no known potential alternatives other than those discussed in Section 7.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

(a) EGRET spacecraft, F. J. Cepollina, (301) 982-5913.

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

Developing of tooling to measure pin/sock engagement and disengagement forces.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-5.7

1. TECHNOLOGY REQUIREMENT (TITLE): Self Aligning Multipin Electrical Connector Assembly PAGE 3 OF 4

8. TECHNICAL PROBLEMS: (Continued)

(c) Connectors must be consistent with requirements of TDRSS, i.e., high power no multipacting.

(d) Connector design must be compatible with megabit data rates.

(e) Connector must have built in verification of proper engagement.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-5.7

1. TECHNOLOGY REQUIREMENT (TITLE): Self Aligning Multipin Electrical Connector Assembly PAGE 4 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Redesign E/U	—																		
2. Modification E/U	—	—																	
3. Qualification E/U		—																	
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)			—																
2. Devl/Fab (Ph. D)				—															
3. Operations					—	—	—	—	—	—	—	—	—	—	—	—	—		
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				△														
NUMBER OF LAUNCHES					2	2	1	2	1	*	1	*	*	1	*	*	*	9

14. REFERENCES:

Flight support system for Earth Observation Satellites (NAS5-23203, Mod 4) SD74-SA-0057.

Letter: NASA/GSFC File No. 8213, Code 730, Subject: "Study of Future Payload Technology Requirements, Contract NAS 2-8272", F. J. Cepollina to H. M. Ikerd, GD Convair, dated 10 January 1975.

In-Orbit Servicing by Frank J. Cepolling and James Mansfield, pages 46-56 Astronautics & Aeronautics, Vol. 13, No. 2, dated February 1975.

Legend: *Resupply missions
E/U Engineering Units

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE 6.1

1. TECHNOLOGY REQUIREMENT (TITLE): Accelerometer Package for Gravity Gradiometer PAGE 1 OF 5

2. TECHNOLOGY CATEGORY: Inertial/Electromechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: Measure steady-state acceleration in the order of 10^{-6} gal (10^{-9} G) with an accuracy of 2 to 3%

4. CURRENT STATE OF ART: Miniature Electrostatic Accelerometers (MESA) have demonstrated capability to measure to 10^{-6} G. (continued on page 4)

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

A gravity gradiometer system, to be used to obtain improved measurements of the earth's gravity field, requires an accuracy of approximately 0.01 EU (10^{-11} gal/cm). The principal instrument in the gravity gradiometer is a set of accelerometers capable of measuring to 10^{-9} G. Current state of the art is illustrated in figure 1, on the next page.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

A. The technology requirement is based on a spinning cruciform gradiometer configuration utilizing four test masses on the ends of the cross. The analyses for the measurement were made in a study by the Jet Propulsion Laboratory "Earth Physics Satellite Gravity Gradiometer Study." (See reference 1) The instrument dimensions have been scaled up from the original version in the JPL study, so that its mass is 30 times that of the original.

B. The Gravity Gradiometer Satellite OP-02A will benefit from this technology advance.

C. The successful development of the gravity gradiometer will be useful in the establishment of an accurate earth subsurface model. This would improve knowledge of structure and density distributions of the base of the continental crust, mountain ranges, deep sea trenches, etc. with resolutions approximating 100 kilometers.

D. The technology program should demonstrate the accuracy of the accelerometer package in the space environment.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE 6.1

1. TECHNOLOGY REQUIREMENT (TITLE): Accelerometer Package PAGE 2 OF 5

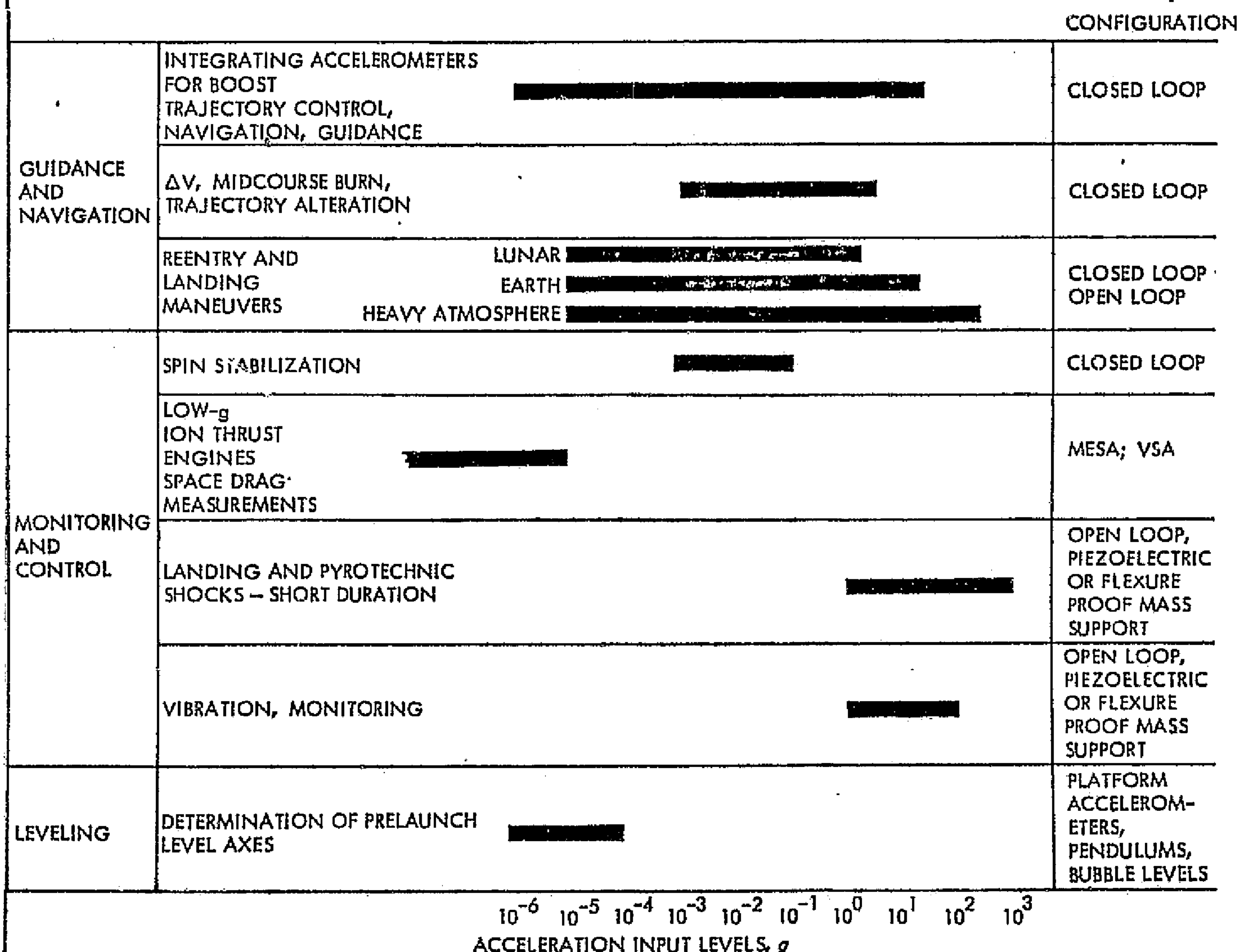

Figure 1. Current State of the Art for Accelerometer Technology

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE 6.1

1. TECHNOLOGY REQUIREMENT(TITLE): Accelerometer Package PAGE 3 OF 5

7. TECHNOLOGY OPTIONS:

Several types of accelerometers will be considered in the investigation:

a. Closed loop integrating accelerometers (used in booster trajectory GNC applications)
b. Piezoelectric strain monitors on the cruciform arms.
C. Miniature Electrostatic Accelerators.
D. Vibrating String Accelerometers.

The MESA is the most likely candidate for the orbital gravity gradiometer application because of its extremely low damping and near zero spring restraint of the suspension system when scaled for a low g environment.

8. TECHNICAL PROBLEMS:

A. High sensitivity
B. Instrument sensitivity to acceleration component due to drag, at low orbits.

In many aspects the orbital application of gravity gradiometer is ideal because of the low acceleration environment. Many of the error sources associated with the terrestrial gravity gradiometer become (continued on page 4)

9. POTENTIAL ALTERNATIVES:

None

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Extensive effort is being carried out on the terrestrial gravity gradiometer for SAMSO.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

A. Precision ephemeris determination.
B. Development of 19-bit A/D converter.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE 6.1

1. TECHNOLOGY REQUIREMENT (TITLE): Accelerometer Package for Gravity Gradiometer PAGE 4 OF 5

Paragraph 4. *Current State of Art (continued)

Bell is presently developing a feasibility model of a rotating accelerometer gravity gradiometer for aircraft applications under funding from the Minuteman SPO of SAMSO, USAF. The performance goal in this case is a randomness of 1 EU as measured through a 10 second time constant. The separation of the Model VII accelerometers for terrestrial gravity gradiometer is 20 cm. For the orbital application the space qualified MESAs would be substituted for the Model VIIs because of the low acceleration encountered in space and the separation between accelerometers is increased to one meter. The goal of .01 EU is therefore realistic.

Currently a noise of about 2 EU is measured for four Model VIIs and the instruments are in the process of being mounted on the rotating fixture for gravity gradient measurements. The feasibility demonstration program for the terrestrial gravity gradiometer is scheduled for completion in mid-1976.

Paragraph 8. *Technical Problems (continued)

negligible in the orbital case. The major unknown parameter is the residual thermal noise of evacuated and modified MESAs. Theoretically a noise level of under.01 EU should be achievable based on present data obtained on Model VII accelerometers, but verification in laboratory is necessary. Another unknown area at this time are the residual drag acceleration components of the satellite at spin or twice spin speed.

* Excerpts from inputs by Dr. Ernest H. Metzger, Chief Advanced Inertial Systems, Bell Aerospace Company.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE 6.1

1. TECHNOLOGY REQUIREMENT (TITLE): Accelerometer Package PAGE 5 OF 5

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. ANALYSES																			
2. MODEL DESIGN																			
3. MODEL MANUFACTURE																			
4. GROUND TESTS																			
5. PROTOTYPE MANUFACTURE																			
6. ROCKET TESTS																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES						1												1

14. REFERENCES:

1. "Earth Physics Satellite Gravity Gradiometer Study" Report #760-70. JPL
2. "Space Vehicle Accelerometer Applications", NASA SP-8102.
3. Comments from Dr. Ernest H. Metzger, Bell Aerospace Company concerning the gravity gradiometer work currently being performed at their facilities.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-7.1

1. TECHNOLOGY REQUIREMENT (TITLE): Life Sciences Organism Holding Units — PAGE 1 OF 5

2. TECHNOLOGY CATEGORY: Life Sciences

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop spaceflight holding units for primates, small vertebrates, cells and tissues, invertebrates and plants, which meet the requirements of the life sciences principal investigators.

4. CURRENT STATE OF ART: Separate small holding units have been flown in past unmanned (Biosatellite) and manned spacecraft. Several prototypes of larger holding (Cont'd on Page 2) HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

Organism holding units are needed to house various research organisms and support whatever research procedures are required by the scientists. Except for primates or other large vertebrates, multiple organisms may be accommodated within each holding unit in order to provide a statistical basis for the observed scientific results. Small vertebrates would be contained in individual cages within one or more holding units to be flown on each mission. Holding unit design emphasis will initially be placed upon the support of vertebrates, and cells and tissues since these types of organisms can be used more directly in the study of spaceflight effects on man.

In addition to a controlled atmospheric environment for the organisms (see Table 1 for typical environmental requirements) the holding units may have to provide one or more of the following, depending upon the research being conducted: (1) Data acquisition interface equipment for monitoring the organism without electromagnetic inter-

(Cont'd on Page 2) P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. The use of organisms in spaceflight experiments will require some sort of holding facility. Many varieties of organisms have been proposed because of the nature of the research being performed. Such organisms include monkeys, rats, mice, turtles, chickens, quail, rabbits, fish, frog and fish eggs, tissues, cultures, marigolds, algae, flies, spiders, etc. Some organisms and experiments involve the use of radioactive tracers which should not enter the crew environment. Other experiments require special atmospheric conditions such as temperature, gaseous composition, pressure, etc. (ref. Table I). Metabolic experiments require special measurement devices associated with feeding, watering, and waste management. Plant experiments may require special lighting characteristics and scheduling. All of the above requirements can be met in the form of one or more special holding units designed with these requirements in mind.

b. The payload which will benefit from this development will be the Life Sciences Shuttle Laboratory (LS-09-S), and the Life Sciences Mini-Labs (LS-10-S).

c. Allows populations of various organisms to be flown and maintained. Allows for statistical numbers (>30) of organisms.

d. Reliability improvement of operational models is required.

TO BE CARRIED TO LEVEL 9

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4. CURRENT STATE OF ART (Cont'd)

units have been built and are currently being reviewed and/or tested by NASA for future application.

5. DESCRIPTION OF TECHNOLOGY (Cont'd)

ference (EMI); (2) Special feeding and watering equipment to provide for accurate measurement of these functions; (3) Bio-waste collection and management equipment; (4) A containment shroud or device to allow crew access to the organisms without organism escape into the cabin or cabin contamination; (5) Noise and vibration abatement features; (6) Special lighting provisions; (7) Provision for photographic or video coverage of the organisms within the holding unit.

Past organisms in spacecraft have been housed in small enclosures specific to the particular experiment being conducted. Very limited manipulation of these organisms has been performed by the crew. Biosatellite experiments were unmanned and generally quite specific in nature. Current holding units potentially applicable to future spaceflights include: (1) the Convair Common Holding Unit, (2) the Monkey Pod being developed at the University of California, and (3) orbiting primate prototype monkey housing units developed by Lockheed and Northrup.

TABLE I. LIFE SCIENCES HOLDING UNIT REQUIREMENTS

		PRIMATES LS-041	NON-PRIMATE VERTEBRATES LS-040	CELLS & TISSUES LS-060	PLANTS LS-050	INVERTEBRATES LS-070
Temperatures*	Range, °F	68 - 86	70 - 86	64 - 100	62 - 82	50 - 99
	Tolerances, ±°F	±1	±1	±1	±1	±1
Humidity*	Range, %	45 - 70	40 - 78	67 - 100	51 - 92	16 - 91
	Tolerances, %	±2	±3	±2	±2	±2
Atmospheric Pressure	Nominal	1 Atm	1 Atm	1 Atm	1 Atm	1 Atm
	Max CO_2 partial pressure, torr	3	3	3	7.6	3 - 7
Lighting	ft-cd	90 ± 10	90 ± 10	90 ± 10	Daylight fluorescent 100 ± 10	0 - 120
Sound Isolation, d.b.		TBD	TBD	TBD	TBD	TBD
Vibration, EMI, Radiation		TBD	TBD	TBD	TBD	TBD
Food Management		Demand or controlled feed. Stored pellets.	Demand or controlled feed. Stored pellets or paste type feed.	Stored Nutrients	Stored Nutrients	Stored Nutrients
Waste Management		Removal, collection & separation	Removal, collection & separation	TBD	TBD	TBD

*Controllable at any point within range.

DBH 8/1/74

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. C-7.1

1. TECHNOLOGY REQUIREMENT(TITLE): Life Sciences Organism Holding Units — PAGE 3 OF 5

7. TECHNOLOGY OPTIONS:

Options in the holding unit design include size, shape, internal configurations, the use of restrained organisms as opposed to unrestrained organisms. The size and number of internal cages for small organisms would be open to future studies. Also, mixing various compatible types of organisms within one holding unit should be considered.

8. TECHNICAL PROBLEMS:

The holding unit must be designed for broad application. It will be used not only in flight but pre- and post-flight and for ground testing in the principal investigator's laboratory. Thus, its size, internal configuration, electrical power interconnections, coolant interconnections, weight, and other properties must be compatible with all the environments in which it will be used, both in 0-g and 1-g. The holding unit should be sealable for those experiments which cannot intermix the air ventilating the organism

(Cont'd on Page 4)

9. POTENTIAL ALTERNATIVES:

a. Some experiments may be capable of being performed without a holding unit. For example, limited plant experiments might be performed within the cabin environment. This alternative, however, will not be satisfactory for many experiments which require controlled environmental conditions, atmospheric isolation, controlled data acquisition, etc.

(Cont'd on Page 4)

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP is currently under review at NASA Headquarters. The COR will be Bill Patterson at NASA/MSFC.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

Several related technology areas may be the subject of independent study such as organism feeding systems, zero-g mass measurement of unrestrained animals, and waste measurement systems which can be used in metabolic studies. Operational problems associated with loading and unloading organisms from the Space Shuttle/Spacelab may also be studied independently.

8. TECHNICAL PROBLEMS (Cont'd)

with that of the cabin.

Organism feeding, watering and waste systems must not only be compatible with 0-g, but for some experiments must provide accurate measurements of the quantities consumed or produced. EMI will undoubtedly be a problem with low voltage electrophysiological signals.

Spacecraft operational factors will have to be taken into account in holding unit development. These may include: (1) loading and unloading of the holding unit, (2) orientation of the holding unit and organisms during various flight and ground phases of the mission, (3) vibration and acceleration loads, (4) refurbishment between flights, (5) modifications to the holding unit to accommodate a new type of organism or a mixture of organisms, and (6) subsystem support of the holding units including electrical power, thermal control fluids and data management functions.

9. POTENTIAL ALTERNATIVES (Cont'd)

b. Another alternative to the use of a general purpose holding unit would be the use of specific holding units or cages for each organism and experiment. This concept is not considered to be a good approach since it would be costly and would result in many problems in mission operations, spacecraft integration, and research program coordination.

14. REFERENCES:

Study of Common Holding Units and Environmental Control Systems for Biological Organisms in Spacecraft Laboratories, General Dynamics/Convair Aerospace Planning Document No. PD663-74-003, San Diego, CA, August 1974.

Life Sciences Payload Definition & Integration Study, Task C&D, CASD-NAS-73-003, Vols. I, II, III & IV, Contract NAS8-29150, General Dynamics/Convair Aerospace, Aug. 1973.

A Study of Environmental Control and Life Support Systems for Spacecraft Animal Experiments, Report No. GDC-ERR-1401, General Dynamics/Convair Division, San Diego, CA, Dec. 1969.

Implementation Techniques for a General Space Bioresearch Laboratory, Report No. GDCA-ERR-1657, General Dynamics/Convair Aerospace Division, San Diego, CA, Jan. 1972.

Space Bioexperiments Support and Transfer Equipment Fabrication and Testing, Report No. GDCA-ERR-1716, General Dynamics/Convair Aerospace Division, San Diego, CA, Dec. 1972.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-7.1
1. TECHNOLOGY REQUIREMENT (TITLE): Life Sciences Organism Holding Units	PAGE 5 OF 5

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Conceptual Design & Planning Study																			
2. Prototype Design, Fab. & Test																			
3. Flight Sys. Design, Fab., Qual.																			
4. P.I. use & baseline data accumulation																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations					T1	●●	●●	●●	●●	●●	●●	●●	●●	●●●	●●●	●●●	●●●		
					T2	●●	●●	●●	●●	●●	●●	●●	●●	●●	●●	●●	●●		

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE			T															
NUMBER OF LAUNCHES						4	4	4	4	4	4	4	4	5	5	5	5	52

14. REFERENCES: (See Page 4)

Legend:

T = Technology

● = Sortie Operations

T1 = LS-09-S, Life Sciences Shuttle Laboratory

T2 = LS-10-S, Life Sciences Mini-Labs

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. C-7.2

1. TECHNOLOGY REQUIREMENT (TITLE): Bioresearch Centrifuge — PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Life Sciences

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop a continuous rotation centrifuge capable of supporting live organisms for up to 30 days.

4. CURRENT STATE OF ART: Ground-based centrifuges have been used for providing hypergravity. A centrifuge for space research is presently only conceptual

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

The basic requirement is to provide a control 1-g environment for organisms (i.e., rats, plants, etc.) for up to 30 days. Provisions for food and waste management, the collection of data and samples (blood, urine, tissues), and the ensurance of minimum disturbance must be considered. Drive and balance mechanisms for the envisioned 3.6 m diameter centrifuge are of particular concern.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a) The 1-g environment provided by the Bioresearch Centrifuge permits normogravity control organisms to be aboard the Spacelab and direct comparison of results with the zero-g organisms. On-board 1-g controls instead of earthbound controls obviate the simulation of launch and re-entry stress conditions on the earth controls.

b) The Bioresearch Centrifuge is to be used in conjunction with the Life Sciences Shuttle Laboratory, LS-09-S.

c) The centrifuge enables life sciences experiments in space under variable but controlled g levels, including reconditioning after a period of near zero "g" prior to reentry.

d) Final test is in space on a Shuttle sortie mission.
Initial but partial technology demonstration test will be performed in laboratory.

TO BE CARRIED TO LEVEL 5/7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-7.2

1. TECHNOLOGY REQUIREMENT(TITLE): Bioresearch Centrifuge

7. TECHNOLOGY OPTIONS:

1) Maintenance of the 1-g environment at the organism location is of prime importance. The effects of g-gradient, Coriolis forces, angular velocity variations have to be investigated.
2) Ventilation: Passive - Forced air flow-through using scoops.
   Active - Blower.

8. TECHNICAL PROBLEMS:

1) Removal of specimens and samples while continuously rotating or possible stoppage.
2) Providing and recording food and water during rotation.
3) Automatic counter-balancing system especially for manned interface with centrifuge.
4) Provisions for telemetry of biophysiological data.

9. POTENTIAL ALTERNATIVES:

For small organisms (cells & tissues, invertebrates) a small, laboratory-style, commercial centrifuge could be adapted to provide the 1-g environment.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Possible requirements study done by NASA/ARC beginning in CY 75.

EXPECTED UNPERTURBED LEVEL 3

11. RELATED TECHNOLOGY REQUIREMENTS:

Development of organism holding units which will be used on the centrifuge. These provide the environmental and physical housing for the 1-g controls.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-7.2

1. TECHNOLOGY REQUIREMENT (TITLE): Bioresearch Centrifuge PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Concepts and Trades																			
2. Exp. Model Design																			
3. Exp. Model Fab.																			
4. Test and Evaluation																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				X					X									
NUMBER OF LAUNCHES										2	2	2	2	2	2	2		14

14. REFERENCES:

SSPDA: Payload LS-08-S - Life Sciences Bioresearch Centrifuge, Summarized NASA Payload Descriptions, MSFC, Oct. 1973.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-7.3

1. TECHNOLOGY REQUIREMENT (TITLE): Teleoperator Subsystems PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Life Sciences

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development of display, manipulator controller and end effectors for teleoperator application.

4. CURRENT STATE OF ART: There are several earth-based teleoperator systems. However, technology deficiencies exist in certain subsystem areas.

HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

Advanced technology is needed with respect to teleoperator systems (e.g., Free-Flying Teleoperator, and Shuttle Orbiter Remote Manipulator) in at least the following three areas:

1. Video display capable of providing high-resolution, three-dimensional picture that in effect places the operator at the end-effector site.
2. Manipulator/Grappler and controllers for providing the sensitivity, light-to-heavy grappling power and resolution desired.
3. End effectors which can secure all types of payloads with sufficient but not excessive force.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. These technology problems evolve from functional analysis of the teleoperator reqmts.

b. This technology is required for the Free-Flying Teleoperator payload, LS-04-S. The advanced technology is required for experiments in the manned systems integration research areas.

c. Implementation of the teleoperator capability would enable supplement EVA as a means for spacecraft and experiment equipment repair and service in orbit.

d. This technology advance requirement will be met with a final test in orbit on a Shuttle flight.
Initial test may be performed at the Lunar landing simulator site at Langley Research Center to demonstrate the technology readiness.

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TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-7.3

1. TECHNOLOGY REQUIREMENT(TITLE): Teleoperator Subsystems PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

a) Displays - It is possible that existing displays such as a seven-inch monitor developed for Skylab could be used. However, a technology study of video parameters such as illumination, color vs B/W, and stereo vs. two-dimensional multi-camera systems is required.

b) Sensor Systems - Trade studies of advanced sensors, e.g., touch, position, optical ranging, force, etc.

c) Control - Pre-programmed vs. master/slave operation.

8. TECHNICAL PROBLEMS:

a. End effector action and reaction.

b. TV camera three-dimensional perception effectiveness.

c. Remote manipulator controls feedback servicing effectiveness.

d. Range-and-range-rate sensor to supplement TV.

9. POTENTIAL ALTERNATIVES:

a) Display Systems - Rather than strictly analog TV sensors and display digital processing may add 3-D information at increased cost and complexity.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. W 74-70347 (502-03-32) Artificial Intelligence for Integrated Robot Systems, Robert Powell, JPL

b. W74-70791 (970-23-20) Teleoperator Manipulator and End Effector Technology, H. P. Kleen, ARC

c. W74-70823 Remotely Manned Systems Displays and Supervisory Control(Requirements for Payload Work Station Design), J. R. Thompson, MSFC, Huntsville, Ala.

d. W74-70824 (970-63-10), Teleoperator Control and Manipulation, W. G. Thornton, MSFC Huntsville, Ala. (Ph. 205-453-5530)

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

Range-Rate Sensor (a separate development) will be coupled with the display/control aspects of the teleoperator system for payload retrieval missions.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-7.3

1. TECHNOLOGY REQUIREMENT (TITLE): Teleoperator Subsystems PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY							For												
1. Basic Research	—	—					Display Systems												
2. Design/Fabrication		—	—				End Effectors												
3. Test, Evaluation and Concept Improvement			—	—			Manipulators/Controllers												
4. Final Test in Space							—	—	—										
5.																			
APPLICATION Free-Flying Teleoperator Development																			
1. Design (Ph. C)		—	—	—															
2. Devl/Fab (Ph. D)				—	—	—													
3. Operations							•	••	•	•	•	•	•	•	•	•	•		
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				X			X											
NUMBER OF LAUNCHES							1	2	1	1	1	1	1	1	1	1	1	12

14. REFERENCES:

1. SSPDA: Payload LS-04-S, Free-Flying Teleoperator, Summarized NASA Payload Descriptions, MSFC, July 1974.

2. Shuttle Free-Flying Teleoperator System Experiment Definition, NAS8-27895, Bell Aerospace, June 1972.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-7.4

1. TECHNOLOGY REQUIREMENT (TITLE): Surgery in Space PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Life Sciences

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop techniques for performing surgery on animals in 0-g.

4. CURRENT STATE OF ART: Routine surgery in 1-g is highly developed.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

There are several unknowns concerning surgery on animals or emergency surgery on humans in the space environment. The principal concerns are:

1. Retention and control of tools and instruments.
2. Confinement of fluids (e.g., blood), tissues, specimens.
3. Visibility and manipulation of animal contained within shrouded area.
4. Maintenance of a sterile field about the surgery site.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Techniques are derivable from ground and Skylab experience.

b. Benefiting payloads:
Any Life Sciences payloads containing animals as research subjects or humans.
In particular - Life Sciences Shuttle Laboratory, LS-09-S
- Life Sciences Mini-Labs, LS-10-S

c. Justification for advancement:
Surgery on animals in the space environment will be required for autopsy, biopsy, sensor implementation or removal, stress induction and, in the case of humans, minor emergencies. It will be needed to provide a research program similar to that found in the principal investigator's laboratory where such surgery is routine.

d. Final test is in space on a sortie flight.
Initial technology tests would be performed on a zero-gravity simulator.

TO BE CARRIED TO LEVEL 5/7

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-7.4
1. TECHNOLOGY REQUIREMENT(TITLE): Surgery in Space	PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

Reference 1 details the following technology development areas. These are only examples of potential approaches to required technology for performing surgery in space.

a) Zero-G Equipment Restraint - A device fabricated of small diameter surgical rubber tubing or large rubber bands secured in holes or notches properly positioned in a light-weight frame to produce an open elastic grid. Test tubes, pencils, syringes, petri dishes, reagent bottles, beakers, etc., can be rapidly secured by insertion between slightly stretched rubber bands at a position on the double grid where the spacing was somewhat smaller than the size of the object to be secured.

b) Air Flow Zero-G Work Surface - The air flow zero-g work surface is a screen or other perforated surface attached to an air duct and blower to induce a stream of air through the surface and provides a positive force acting to hold items against the work surface.

c) Flexible Shroud - A transparent, flexible shroud for debris containment. The shroud is equipped with arm slits to enable the experimenter to gain access to all equipment within the shroud. With the shroud positioned over the area in front of the animal housing unit, all other equipment items required for animal handling procedures are located within the shroud.

d) Vertebrate Management Kit - A kit providing tools and devices for restraining small animals during surgery. Includes harness-type restraints and a universal animal dissection board.

9. POTENTIAL ALTERNATIVES:

Reference 2 includes other potential solutions.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. Concept Verification & Test (CVT) at NASA/JSC to test some initial concepts.

b. A working prototype of an ARC developed multipurpose workbench/surgery table was tested in the ARC/MSFC CVT in July 1974. Further in-house work is in progress to upgrade this unit. The initial tests were quite promising.

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

Development of organism holding units and interface elements for performing animal surgery.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-7.4

1. TECHNOLOGY REQUIREMENT (TITLE): Surgery in Space PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Technique Improvements	—																		
2. Experiment Technique Design		—																	
3. Experiment Technique Ground Test		—																	
4. Zero g Simulations in Water Tank			—																
5. Evaluation				—															
APPLICATION																			
1. Design (Ph. C)					—														
2. Devl/Fab (Ph. D)						—													
3. Operations							●●	●●	●●	●●	●●	●●	●●	●●	●●	●●			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				X														
NUMBER OF LAUNCHES							2*	2	2	2	2	2	2	2	2	2		20

14. REFERENCES:

1. Life Sciences Payload Definition and Integration Study, NAS8-30288, August 1974.

   New Technology Reports submitted to NASA/MSFC in conjunction with NAS8-30288:
   a) Zero-G Equipment Restraint
   b) Air Flow Zero-G Work Surface

2. NASA Technical Brief 10887, soon to be published.

* Life Sciences Shuttle Laboratory, LS-09-S.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-8.1

1. TECHNOLOGY REQUIREMENT (TITLE): Active Cleaner PAGE 1 OF 7

2. TECHNOLOGY CATEGORY: Contamination

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop this technology to a level that will permit in-situ cleaning of contaminant sensitive surfaces.

4. CURRENT STATE OF ART: Laboratory investigations and OGO-6 experiments have demonstrated the feasibility of active cleaning using gas plasmas. Removal rates of between 3.5×10^{-13} and 10^{-7} gm/cm^2-sec. have been demonstrated. No equipment has been flown on orbiting payloads. HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

Contamination

Contamination of optical surfaces is a severe problem for orbiting payloads. Contaminants can be introduced during manfacture, test and launch operations. Payload designs sometime preclude the pre launch cleaning of these optical surfaces.

Outgassing of the payload structure from plastics, seals, paints and lubricants also causes contamination following launch. If the contaminants are subjected to UV radiation, the resulting deposit becomes polymerized and very difficult to remove.

Research under NASA contracts has shown that severe reflectance degradation in the UV range (0.1 to 0.3 micron) occurs with film depositions of 10^{-6} gm/cm^2. Deposition rates of 4×10^{-12} gm/cm-sec. were observed on one of the Skylab Contamination Monitors. Data from the OGO-6 contamination experiment indicated a 9×10^{-11} gm/cm^2-sec. deposition rate during the early part of the mission.

Active Cleaning

Laboratory experiments carried out by the Boeing Company under NASA contract have demonstrated contamination removal rates of 10^{-7} gm/cm^2-sec. using Oxygen, Argon, Hydrogen and Helium plasmas. Plasma powers ranged from 30 to 50 watts. Efficiency of cleaning varied from partial to complete recovery of reflectance of the test samples.

The mechanism involved in the cleaning process is unknown, but evidence indicates that chemical reactions are not involved to a significant extent.

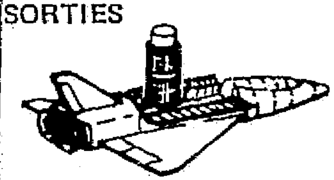
(See pages 2 and 3 for additional description.)

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

5. DESCRIPTION OF TECHNOLOGY (Cont'd)

INSTRUMENT REQUIREMENTS
Surface Cleaning (With Plasma Jets)

CONTAMINATION-SENSITIVE SORTIES & SPACE TECHNOLOGY SORTIES

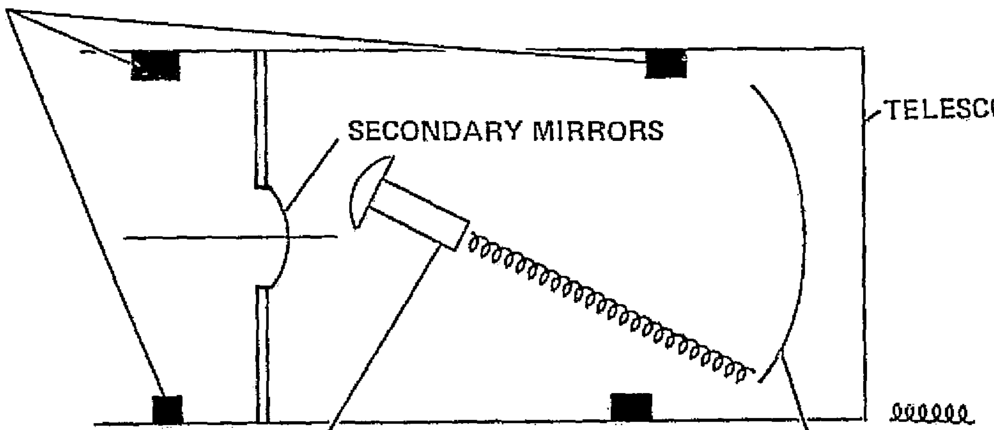


MISSION REQUIREMENT (COOLED TELESCOPE MISSIONS)

EXTEND TELESCOPE USEFUL LIFE BY PERIODIC REMOVAL OF CONTAMINANT DEPOSITION

CLEANING REQUIREMENT

REDUCE WAVEFRONT ERROR CAUSED BY DEPOSITION TO TOLERABLE VALUES BY CLEANING & PLASMA POLISHING (UP TO 3-m DIAMETER MIRRORS)



(TEMPORARILY SUPPORTED BY SECONDARY MIRROR STRUTS, GIMBALED FOR SYSTEMATIC SCAN OF MIRROR SURFACE)

5. DESCRIPTION OF TECHNOLOGY (Cont'd)

CONTAMINATION – SURFACE CLEANING WITH PLASMA JETS

ITEM	CAPABILITY REQUIRED	STATE OF ART*
MEASURE OF CONTAMINANT TYPE & MASS RANGE (AMU)	1 TO 300	2 TO 150
DEPOSITION MEASUREMENT RESOLUTION (g/cm^2)	1×10^{-11}	1×10^{-10}
DEPOSITION MEASUREMENT RANGE (g/cm^2)	1×10^{-10} TO 1×10^{-5}	1×10^{-9} TO 1×10^{-4}
CLEANING AREA (cm^2)	10,000	100
CONTROLLABILITY OF CLEANING RATE (g/cm^2 SEC)	2×10^{-10}	10^{-7}

*OGO-6, GROUND-BASED LABORATORIES

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-8.1

1. TECHNOLOGY REQUIREMENT (TITLE): Active Cleaner PAGE 4 OF 7

6. RATIONALE AND ANALYSIS

a. The total deposition and deposition rates recorded from the OGO-6 experiments were from 5 to 10 $\times 10^{-6}$ gm/cm^2 deposition and up to 9 $\times 10^{-11}$ gm/cm^2-sec. deposition rate. Based on these records, deposit removal rates should exceed these by 2 to 3 orders of magnitude, i.e., 10^{-7} gm/cm^2-sec.

The larger and more complex payloads envisioned for launch by Space Shuttle will be subjected to contamination rates well in excess of the maximum rates recorded by OGO-6. The Space Shuttle Sortie missions will be especially severe with RCS, material outgassing and waste dumps. Further experiments are needed to determine the removal rates required for these payloads. Shields and doors protect only on ascent and descent, not during observation.

b. All astronomy payloads, Earth Resources payloads, and miscellaneous payloads using optical surfaces or ports will benefit.

c. Degradation of transmission or reflectance can render an experiment useless, even though the supporting payload systems continue to operate. The ERTS-1 Multi-spectral Scanner calibration system was useless when activated, apparently due to contamination. Even moderate contamination can render the payload performance so low as to be worthless as a scientific experiment. Additional benefits result from fewer spacecraft required or fewer shuttle retrival missions.

d. To be used as a method for extending the useful life of spacecraft optics, active cleaners must have demonstrated successful prototype qualification.

This will include on-orbit tests using a variety of gases, plasma powers, and surface scanning methods. The qualification must also include tests on a variety of contaminants including UV exposure on the various test samples. Final test will be in orbit on a Shuttle sortie flight.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-8.1

1. TECHNOLOGY REQUIREMENT(TITLE): Active Cleaner

7. TECHNOLOGY OPTIONS:

The critical parameter is the removal rate. This parameter is affected by:

a. Plasma power
b. Type of gas used to generate the ionized plasma.
c. Distance from plasma orifice to surface treated.
d. Type of contaminant.

The first three items can be varied to affect removal rates. Plasma power and the beam forming methods used can both be optimized for a particular application. The beam power would vary from 10 to 100 watts, depending on the beam cross section, the contamination to be removed and the speed of removal required. Various types of gas can be used including Argon, Oxygen, Helium and Hydrogen. Further study is needed to determine the optimum gas and power for a specific surface.

(Continued on page 6)

8. TECHNICAL PROBLEMS:

Inaccurate control of the plasma could cause erosion of the optical surface overcoating. Structure, lubricants and seals adjacent to the treated surface will have to be shielded from the plasma to minimize re-contamination of the optical surface. Improved techniques are needed to insure ignition, treat large surfaces and avoid interference with spacecraft communication.

(Continued on page 6)

9. POTENTIAL ALTERNATIVES:

a. Protective Covers.
b. Careful material selection.
c. Cooled sacrificial surfaces.
d. Bake-out in-situ.
e. Long outgassing periods prior to surface exposure following orbit insertion.
f. Retrieval and replacement of degraded surfaces.
g. Avoid deposition in space.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. NASA Contract NAS 8-26385, "Active Cleaning Technique for Removing Contamination from Optical Surfaces in Space."
b. NASA Contract NAS 8-28270, "Active Cleaning Technique Device."

(Continued on page 6) EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

Technology advances in the identification of contamination mechanisms and the elimination of contamination sources through materials research.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-8.1

1. TECHNOLOGY REQUIREMENT (TITLE): Active Cleaner PAGE 6 OF 7

7. TECHNOLOGY OPTIONS (Continued)

The most efficient method for contamination removal is by plasma bombardment. Removal of contamination by plasma bombardment results when the ions in the plasma impact the surface. The removal of material is called sputtering. The cleaning rate is a function of

a) Mass of the bombarding ion
b) Mass of the contamination atoms
c) Ion impact energy
d) Plasma density
d) Angle of incidence
f) Surface finish

Maximum cleaning rates are achieved for high density plasma (mA/cm^2) and impact energies in the 1 to 10 keV range. To clean carbonaceous contamination a neon plasma is most efficient. For higher molecular weight contamination, an argon or krypton plasma would be used.

8. TECHNICAL PROBLEMS (Continued)

Uniform control of the plasma cleaning rate across the contaminated surface is the principle problem in using ion bombardment for cleaning. It will be necessary to maintain removal precision to a few angstroms to avoid damaging optical surfaces.

To maintain uniform cleaning rates a QCM servo-loop to control the plasma generator is needed.

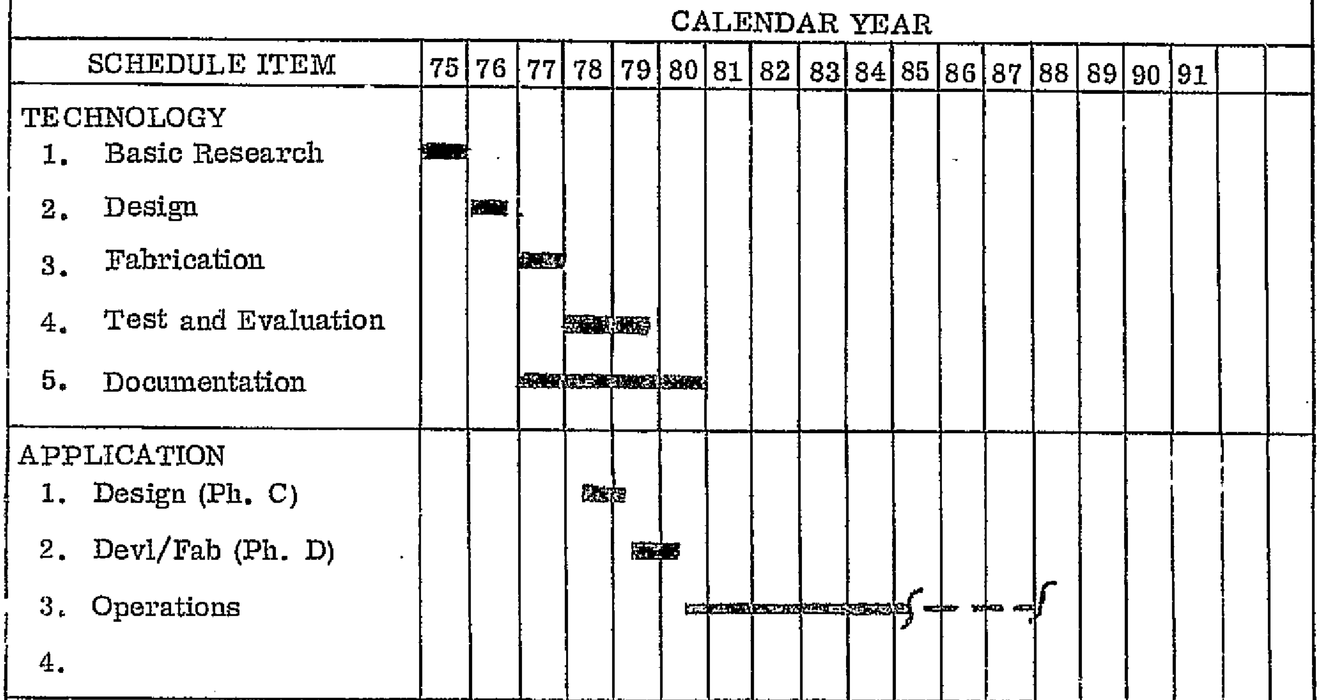
10. UNPERTURBED TECHNOLOGY ADVANCEMENTS (Continued)

At present there is no program to develop a QCM servo control of a plasma contamination removal system. Without such a program it will be impractical to use a plasma cleaning system.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-8.1

1. TECHNOLOGY REQUIREMENT (TITLE): Active Cleaner PAGE 7 OF 7

12. TECHNOLOGY REQUIREMENTS SCHEDULE:



13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE						T												
NUMBER OF LAUNCHES						7	6	6	3	6	5							32

14. REFERENCES:

1. "Control of Contaminants on Sensors" N73-33367
2. "Active Cleaning Technique for Removing Contamination from Optical Surfaces In Space" N73-30697 & N71-35075
3. "A Survey of Contamination of Spacecraft Surfaces" (Contract No. NAS 8-26004)
4. "Space Measurements of the Contamination of Surfaces by OGO-6. Outgassing and Their Cleaning by Sputtering and Desorption" N71-20207
5. "Report on Skylab QCM Performance" N73-31412
6. Comments from Boeing Aerospace Company, Roger B. Gillette, 88-06, Dec. 6, 1974.
7. Comments from Dan McKeown, Foraday Labs, Dec. 18, 1974.

Legend:

T = Technology

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
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6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-8.2

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Contamination Monitors PAGE 1 OF 6
Contaminant identification, rate and deposition measurement accuracy

2. TECHNOLOGY CATEGORY: Contamination

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development of a set of monitoring instruments to correctly identify contaminants in the vicinity of a contamination sensitive payload as well as to measure deposition flow rate and thickness.

4. CURRENT STATE OF ART: Sampling techniques, photometers and quartz crystal microbalance deposition monitors were used in the Skylab flight. Improved units are being planned for a greater dynamic range & accuracy. HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY Improvement is required in the effectiveness of contamination monitoring and warning devices for use in future sortie and automated space payload flights. Primary need is for detection, identification and measurement of contaminants around optical devices quickly enough that contaminant avoidance procedures can be initiated. An order of magnitude improvement in identification and measurement capability is desired. A major contaminant source involves organic contaminants which tend to polymerize into varnish-like coatings on an optical surfaces.

Two classes of contaminant monitors are currently planned: one, to measure Shuttle orbiter bay contamination from high to medium levels; and two, measurement of contaminants within telescopes from medium to very low levels as well as providing alarm and signals to protective doors and devices.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☒ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Contaminants induced by the spacecraft environment have a most deleterious effect on the proper operation of certain payloads and results in the degradation of various sensors, optics and other systems sensitive to these contaminants. This will be especially true with payloads to be transported in and deployed by the Shuttle Orbiter.

Experience gained from the Skylab program has demonstrated the need for advanced sensors to adequately evaluate and control the spaceflight contamination environment. However, Skylab ATM operated with solar "heated" optics, some future sensors will utilize cooled optics and detectors which pose a greater contamination problem.

b. All Astronomy, solar physics, and some high energy astrophysics payloads (particularly in the spectrum from 0.03 to 4 kev) will benefit from the contamination monitor and consequent control measures. Payloads with cooled optics and detectors will benefit greatly from improved contamination control.

c. With adequate knowledge of types of contaminants, quantities, rates of deposition, etc., countermeasures such as closing covers, positive pressurization (purging) may be instituted on orbit. Tests as per ST-08-S for Shuttle bay monitoring are planned. Internal telescope optics need greater protection particularly during sortie missions.

d. Final proof of effectiveness of contamination monitors is in space with an astronomical payload. High to medium level monitors are to be tested on Shuttle Orbiter bay on a sortie flight. Medium to very low level monitors are to be tested in a telescope on a sortie flight.

TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-8.2

1. TECHNOLOGY REQUIREMENT(TITLE): Advanced Contamination Monitors PAGE 2 OF 6

Contaminant identification, rate and deposition measurement accuracy.

7. TECHNOLOGY OPTIONS:

This task is an extension of previous efforts to develop concepts and techniques for monitoring contaminants induced into the spacecraft environment. Three of the concepts to be investigated include a dust fall (surface accumulation and characterization) detector for monitoring selected portions of the orbital particulate induced atmosphere, a detector alarm for trace elements of various volatile matter which results from outgassing and leaks, and a photodiode array to be used as an imaging photometer to define particulates. The first two will be conceptual efforts while the latter will be an extension of a previous development. Other contaminant monitor concepts may include mass spectrometers and other sampling identification devices.

(continued on page 3)

8. TECHNICAL PROBLEMS:

a. Saturation of contamination monitors.
b. Power, weight, and data rate allocations are limited.
c. Long lifetime, refurbishment, low cost.
d. Laboratory temperature control QCM's cannot be used in space until improved thermo electric devices for cooling are developed to withstand the shock and vibration of the launch environment.
e. Improved quartz crystal stability.

9. POTENTIAL ALTERNATIVES:

a. An alternate method of measurement of deposition of organic materials on an inorganic is the use of an X-ray fluorescence monitor which can detect thickness of 5 nm or less with a sensitivity of ± 1 nm.
b. If surfaces can (many optical surfaces cannot) be heated, heating will boil out water, making it easier to concentrate on measurements of organic material.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. MSFC RTOP 909-54-13 Contamination Monitors Development, Robert Naumann

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Development of catalog or reference memory of signatures for identifying contaminants.

7. TECHNOLOGY OPTIONS: (Continued)

Recent advances in solid state electro-optical components have resulted in imaging devices having quantum efficiencies of 0.8 which is several times higher than those currently used with image intensifier systems and SEC vidicon monitors. Concurrently the solid state logic technology field has produced micro-computers occupying volumes of only cubic centimeters. The interfacing of these developments offer the potential of continuous monitoring and analysis of the particulate induced atmosphere near critical experiment view directions in space flight laboratories. The photodiode array system offers particle detection, monitoring, and induced brightness levels as direct data. These properties would facilitate near real time mission timeline planning for affected experiments operations thus significantly increasing the probability of obtaining meaningful data. Present laboratory development and interfacing activities are in progress to evaluate detectability of moving point sources by 32 x 32 and 50 x 50 photodiode array modules. This "breadboard" system is operational and is being tested in the laboratory. The system is providing visual images and brightness values for field of view test items. The objective of this task is to build a larger mat system with increased capability electronic circuits for improving resolution limit and ability to measure lower reflectiveness, i.e. particles at greater speeds.

Integrated Real Time Contamination Monitor Development

The development of the various modules utilizes as much as possible the instruments and techniques developed in the Skylab program for flight and ground tests. The approach is to develop each module independently to the status of a flight type engineering model, capable of being tested under flight simulated conditions. The models are then brought into the laboratory and incorporated as instruments in various contamination research programs and flight test programs. This allows a gain practical experience in the performance of the instrument and an incorporation improvements as they become necessary. In some instances the engineering model could be flight qualified and flown if the opportunity presents itself. The status of each module is:

a. Deposition monitors in the form of quartz crystal microbalances have been successfully flown on Skylab and have yielded the bulk of our current knowlege of deposition of condensibles. One of the lessons learned in Skylab is that the amount of material collected is very temperature dependent. In fact, by cycling the temperature or by collecting on two or more surfaces at different temperatures, it is possible to measure the heat of absorption of the material and thereby deduce the type of material. This has led to the thermally controlled QCM (TQCM) which has a small Peltier cooler controlling the crystal temperature. Another version, the ultrasensitive QCM uses 20 MH_Z crystals which allows it to measure a fraction of a monolayer. This unit is presently undergoing evaluation tests. These units are essentially developed to off-the-shelf flight hardware and are small enough to be deployed in a number of locations. Individually or in conjunction with other instruments. TQCMs can be operated down to $140^{O}K$ using a passive radiative cooler. A study

7. TECHNOLOGY OPTIONS: (Continued)

is under way to incorporate a battery of these units into an Air Force satellite to study the interactions of back-scattered H_2O vapor with cryogenic surfaces. Other units that can operate as low as 5^oK are available if cryogenics are on board.

b. A flight quadruple mass spectrometer has been developed that operates from 1-300 AMU with unit resolution at 300 AMU. It is being evaluated at the present and a suitable inlet system must be developed to enable it to perform trace gas analysis at atmospheric pressure. One of the significant features of this system is a computer interface, compatible with the SUM-C Space Lab system, that can unfold complex spectra of a number of substances and give a real-time qualitative and quantitative analysis of a mixture of gases.

c. The optical effects module has been tested in the laboratory and has been used in the Skylab thermal vacuum tests as a contamination monitor. Some design problems were identified in the source and in the placement of the high voltage leads. A subsequent redesign and repackaging in a more convenient form is underway. The system can monitor the transmission, reflectance, and scatter at two different wavelengths in the ultraviolet. This allows the optical constants of the deposited contaminant to be ascertained. In addition, one of the reflection surfaces is a QCM which can measure the deposition responsible for the change. This QCM can also be heated to vaporize the contaminant so that it may be identified by the mass spectrometer. This technique allows identification to be made of trace quantities far below the threshold of a mass spectrometer.

d. A volumetric aerosol detector that can count and size particulates from 0.1 to 30 μm has been developed and used in the Skylab SCGT tests of the waste tank and in the tests of the Shuttle sublimator and evaporator systems to monitor particle production. It has also been used in a variety of other applications such as measuring clean room performance and monitoring fog droplet size in laser penetration tests. The device features two intercavity lasers as sources and represents a unique state-of-the-art instrument for such purposes. The instrument was recently rebuilt and several features such as optical isolators were incorporated to reduce noise. It is currently undergoing evaluation.

e. Skylab experience has taught that accumulated dust fall even in clean room environment can be significant. Therefore, in addition to the volumetric aerosol detector that measures the instantaneous dust content in the ambient environment, a device to measure the integrated dust deposition is required. Ordinary QCM's do not detect dust deposition because the surface accelerations are so high that the weak Van-der-Waal forces that cause particulates to adhere do not couple the particulates to the surface solidly enough to be measured. There is no instrument currently available to actually measure dust fall in situ in a vacuum zero-G situation. Several possibilities exist such as the quartz fibre

7. TECHNOLOGY OPTIONS: (Continued)

microbalance developed by Dudley Observatory to study ice crystal melting in support of Skylab. This type of device will be given primary emphasis in this fiscal year to bring it up to the development status of the other instruments.

f. Attempts to measure scattered light background on Apollo and Skylab using photometers and photography have taught that it is very difficult to make meaningful measurements unless imaging data is available. Photometers cannot distinguish light scattered from structure, sunshield, individual large particles, stars, earth, or moon from a cloud of unresolved particles. Photography has proved more useful, but does not provide real-time read out. Low light level TV would be ideal except that it lacks dynamic range and has too high a data rate. An excellent compromise is the new charge-coupled optical arrays. Such a device for this application is under development and is presently undergoing preliminary tests. Such a device can be coupled with one of the new micro-processers to provide data compression and to act as a moving target indicator to identify individual particles moving through the field.

g. Since some of the proposed Shuttle payloads may use hydroscopic optical coatings, it is important to monitor the partial pressure of H_2O. The gas analyzer could do this, but it may not always be convenient to locate the analyzer near the surfaces in question. Therefore, a small simple H_2O vapor monitor should be developed. Such a device could consist of a QCM with a hydroscopic surface to measure the absorbed H_2O. Other devices based on resistance change in semi-conductors resulting from absorption of various specific molecules may also be applicable.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-8.2

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Contamination Monitors PAGE 6 OF 6

Contaminant identification, rate and deposition measurement accuracy

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Previous experience analysis (baseline)																			
2. Concepts & trades analysis																			
3. Exp model design																			
4. Exp model fabrication																			
5. Test and evaluation																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				T														
NUMBER OF LAUNCHES					26	26	26	26	26	26	26	26	26	26	26	26	26	338

14. REFERENCES:

a. Faraday Labs, NASA MSFC Contract NAS 8-31110, "Cryogenic Quartz Crystal Microbalance".

b. Faraday Laboratories, NASA MSFC Contract NAS 8-27879, "Thermoelectrically - Cooled QCM".

Legend:

T = Technology

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-8.3

1. TECHNOLOGY REQUIREMENT (TITLE): Contamination Process Mechanisms; effects vs temp, time, radiation exposure, interactions, production and distribution

2. TECHNOLOGY CATEGORY: Contamination

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development of further understanding of contamination mechanisms, effects, production and distribution rates. Greater problems are expected with the advent of cooled telescopes and detectors especially where greater photometric and spectral accuracy is desired in experiment observatory.

4. CURRENT STATE OF ART: Some effects of contamination process were studied during preparation of components for Skylab flights, including guidelines for contaminant avoidance.

HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY - All spacecraft encounter contaminants induced by the environment in which they are transported and operate and also by the atmosphere internal to the spacecraft. These contaminants can cause degradation of critical optical systems by deposition on lenses and mirrors and by absorbing, scattering or attenuating the signal when particulates obstruct the field of view. Although much has been determined experimentally post facto about effects of contamination, little investigation has occurred into understanding the exact mechanisms by which gaseous contaminants in the presence of ultrviolet and radiation convert into "varnishes" or a golden brown film as experienced in Skylab.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. An understanding of contamination sources and mechanisms or processes enables the user to avoid contaminant damage.

b. All payloads with optical windows and optical element surfaces will benefit from application of knowledge gained.

c. A better understanding of the role of contaminants in interfering with observation processes as well as mechanisms causing the contaminants will help improve all project plans and strategies for avoiding or circumventing the contaminants.

d. Final test of understanding is in space on sortie flights which tend to affect all contamination elements.

Theory to be developed by 1977.

TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-8.3

1. TECHNOLOGY REQUIREMENT(TITLE): Contamination Process Mechanisms; effects vs temp,time,radiation exposure,interactions, production and distribution

7. TECHNOLOGY OPTIONS:

A number of theoretical models have been developed for contaminants emission , distribution, chemical conversion, distribution, deposition and interference processes. While much experience with contamination avoidance and measurement tasks has been obtained in a long series of spacecraft flights from the early OAO's to the Skylab flight, there is no universal easy-to-use model or even a catalog of contributing processes leading to understanding of each situation. Each of the models needs to be evaluated and the apparent results need to be tabulated. The accuracy of the results predicted by each model would be compared against metric measurements accumulated from previous flights.

(Continued on Page 3

8. TECHNICAL PROBLEMS:

a. Several models in existence plus many papers and guidelines published, need clarifying and update philosophy.
b. Much of previous experimental data being lost versus time (some could be used to verify updated theory).
c. Funding for experimental work at a minimum.

9. POTENTIAL ALTERNATIVES:

A study is needed to consolidate past experience and to adjust previous theoretical models possibly resulting in new mathematical models capable of explaining the processes more effectively.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. Development of an Integrated Real Time Contamination Monitor, MSFC 755-49, April 19, 1974.
b. Instrumentation (Contamination Monitors), MSFC 909-54-13, July 9, 1974.

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

a. High resolution IR, visible, UV, XUV telescopes and instruments.
b. High resolution X-ray telescopes, instruments and arrays.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-8.3

1. TECHNOLOGY REQUIREMENT (TITLE): Contamination Process Mechanisms; effects vs temp, time, radiation exposure, interactions, production and distribution.

7. Technology Options: (Continued)

Ultimately one will see the weaknesses of each model or set of explanations for the contamination processes. Where some investigators such as R. L. Shannon and R. B. Gillette have duplicated some of the in space contamination processes on earth in the laboratory, a more exact understanding of those processes exists and these explanations might be included in the total study.

Very good guidelines, based on science as well as experience have been generated by R. J. Naumann and associates, at MSFC, in "Skylab Advanced Environment" and the "Space Transportation System Contamination Monitor Plan" in 1974.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-8.3

1. TECHNOLOGY REQUIREMENT (TITLE): Contamination Process PAGE 4 OF 10
Mechanisms; effects vs temp, time, radiation exposure, interactions, production and distribution.

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Review + comparison of previous knowledge	—																		
2. Concepts for improved model.	—																		
3. Planning of complete model for understand'g		—																	
4. Model and explanation.			—																
5. Test and evaluation			—	—	—	—													
APPLICATION									For the average contaminant sensitive payload.										
1. Design (Ph. C)				—															
2. Devl/Fab (Ph. D)					—														
3. Operations						—	—	—	—	—	—	—	—	—	—	—	—		
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE			T															
NUMBER OF LAUNCHES				26	26	26	26	26	26	26	26	26	26	26	26	26	26	338

14. REFERENCES:

See Attached Bibliography (pages 5 to 10)

Legend:

T = Technology

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-8.3

1. TECHNOLOGY REQUIREMENT (TITLE): Contamination Process Mechanisms: effects vs temp, time, radiation exposure, interactions, production and distribution. PAGE 5 OF 10

BIBLIOGRAPHY

1. ATM Cleanliness Requirements (Apollo Telescope Mount System Cleanliness, Specification for), NASA/MSFC document 50M02412

2. ATM Contamination Follow-on Study, Volume II, Appendices for Last Monthly Report, Ball Brothers Research Corporation, Report TN67-68, Vol. II, 28 Oct. 1967

3. ATM Flight and Prototype Purge Requirements, NASA/MSFC document 50M02538, Rev. B, prepared by PM/SE-ATM.

4. ATM Material Control for Contamination due to Outgassing, Rev V, NASA/MSFC document 50M02442, December 1, 1972

5. ATM Optical Environment Contamination Control and Abatement Plan, Space Sciences Laboratory, MSFC, Huntsville, Alabama, January 10, 1968

6. ATM Prototype Article Thermal Vacuum Test Plan, March 31, 1971 NASA/MSFC document 50M02536

7. Thermal Vacuum Bake-Out Criteria (FLT/Prototype), NASA/MSFC document 50M03663, April 19, 1971

8. ATM Transportation Plan, NASA/MSFC document 50M02420, Rev. A, prepared by Astrionics Laboratory, April 1, 1969

9. Active Cleaning Techniques for Removing Contamination from Optical Surfaces in Space; R. B. Gillette and W. D. Beverly, (Contract NAS8-26385), Boeing Company for MSFC, Quarterly Progress Report No. 2

10. Analysis of a Two-Dimensional Mass Transport Problem in Contamination of Space-Flight Experiments; Edwin Klingman NASA/TMX-64581, February 18, 1971

11. Apollo Applications Program (AAP) Payload Integration, Technical Report, August 29, 1969, Cluster System Contamination Analysis Report, Vol. IV, External Thermal Coating Contamination, Martin Marietta Corporation, Denver Division, ED-2002-893-1

12. Apollo Applications Program (AAP) Payload Integration, Technical Report, Materials Compatibility Analysis For the Multiple Docking Adapter (MDA), Apollo Telescope Mount (ATM), and Related Experiments; Martin Marietta Corporation, Dec. 20, 1968 /ED-2002-523-1

1. TECHNOLOGY REQUIREMENT (TITLE): Contamination Process Mechanisms; effects vs temp, time, radiation exposure, interactions, production and distribution.

13. Apollo Telescope Mount Extended Applications Study Program, Follow-on ATM Contamination Study Task IV, Third Periodic Progress Report; D. B. McPherson and R. B. Morse, Ball Brothers Research Corporation, Report No. TN 67-68, Vol. I

14. Apollo Telescope Mount Extended Applications Study Program - ATM Contamination Study Task IV, Final Report prepared for NASA by BBRC under contract NASw-1386, March 10, 1967

15. Atmosphere in Space Cabins and Closed Environments, ed. Karl Kemmermeyer, Appleton-Century-Crofts, New York 1966

16. Attitude-Control Rocket Exhaust Plume Effects on Spacecraft Functional Surfaces, F. G. Etheridge and R. A. Boudreaux, J. Spacecraft 7:44

17. Briefing (on) NASO Large Space Telescope, ITEK 71-3100-1, Feb. 1, 1971

18. Cleanliness Requirements for Space-Borne Optical Sensors, D. C. Smith, Hughes Aircraft Co., AIAA Paper No. 71-471, AIAA 6th Thermophysics Conference, Tullahoma, Tenn., April 26-28, 1971

19. Cluster System Contamination Report, Vol I, Contamination Sources Report, Skylab Program Payload Integration, Martin Marietta-Denver Division, ED-2002-879, Vol. I

20. A Compilation of Low Outgassing Polymeric Materials Normally Recommended for GSFC Cognizant Spacecraft, Aaron Fisher and Benjamin Mermelstein, Special Materials and Projects Office Materials Engineering Research Branch, July 1971; GSFC, Greenbelt, Maryland, (NASA-TM-X-65705)

21. Contaminant Particle Trajectories Near a Spacecraft, R. Grenda et al., Space Research IX-North Holland Publishing Co, Amsterdam (1969)

22. Contamination Control and Environmental Protection of Space Vehicles and Associated Equipment, Procedures for, MSFC-PROC-151

23. Contamination Control Handbook, Washington, NASA 1969, 314 p. refs. Sandia Corporation, (NASA Order H-13245A), (NASA-CR-61264, NASA-SP-5076)

24. Contamination Control Principles (Sandia Corporation), NASA-SP-5045

25. Cross-Check Study of Thermal Vacuum Weight Loss Determinations for Selected Polymers, by C. T. Egger, et. al., NASA TM X-53106

26. Direct Observation of Particulate and Impact Contamination of "Optical" Surfaces in Space, by D. S. Hallgren and C. L. Hemenway, Space Research IX - North-Holland Publishing Company, Amsterdam (1969), p. 102

27. Effect of Vacuum on Materials, by Henry E. Frankel of NASA-Goddard SFC, ESRO TN-77, NASA-TM-X-61789, January 1969

28. Evaluation of Orbital Optical Contamination Phenomena and its Effects on Astronomical Experiments, by A. L. Sherman and J. Majoros, AIAA Paper No. 71-74, AIAA 9th Aerospace Sciences Meeting, New York, New York, January 25-27, 1971

29. External Spacecraft Contamination Modeling and Countermeasures, by T. Baurer, et. al. (General Electric Company), June 1970, pp. 85, Rept-70SD260

30. Further Studies on M_gF_2-Overcoated Aluminum Mirrors with Highest Reflectance in the Vacuum Ultraviolet, by L. R. Canfield, G. Hass, and J. E. Waylonis, Applied Optics 5:45 (1966)

31. GSFC Micro-Volatile Condensable Materials System for Polymer Outgassing Studies, A, Fisher, et. al., October 1969, pp. 36, NASA-TM-X-65399)

32. Handling and Environmental Requirements for ATM Solar Modules, Procedures NASA MSFC Doc. 40M26359

33. Indentification of Volatile Contaminants of Space Cabin Materials, by J. V. Pustinger, Jr., et.al., Final Report, January 1967 - February 1968 (Monsanto Research Corporation), July 1968; pp. 178, (NASA-CR-97918)

34. Instrumentation Package for a Large Space Telescope (LST), GSFC X-670-70-480, November 1970

35. Laboratory Experiments to Study Surface Contamination and Degradation of Optical Coatings and Materials in Simulated Space Environments, by G. Hass and W. R. Hunter, Applied Optics 9:2101 (1970)

36. Large Space Telescope-Continuation of a Technology Study, Final Report; September 3, 1971, ITEK 71-9463-2

37. Large Space Telescope (LST); Preliminary Analysis and Design Report, December 1971, Goddard Space Flight Center, Greenbelt, Maryland

38. Large Space Telescope (LST), Preliminary Study, Volume II, Technical Report, by Program Development, February 25, 1972, NASA/MSFC

39. Large Telescope Experiment Program (LTEP), Volume 1, Part 2, Perkin-Elmer Corp., 24 April 1970, 512 p. refs. (Contract NAS8-21497), (NASA-CR-102769, Rept. 9800, Volume 1, pt 2), Avail. CFSTI CSCL 17H

40. Light Scattering by Manned Spacecraft Atmospheres, by Kovar, Kovar, and Bonner, Planetary and Space Science 17:143, February 1969

41. MSC Contamination Control Program Requirements Manual, Vols. 1and 2, Sept. 1970, (NASA-TM-X-66541)

42. Molecular Contamination in Environmental Testing at Goddard SFC, J. C. Goldsmith, et.al. (NASA), October 1970, pp 24, Paper No. 2, ASTM/IES/AIAA Space Simulation Conference, September 14-16, 1970, (NASA-TM-X-66936)

43. A Neutral and Ion Mass Spectrometer for Environmental Gas Composition of the ATM, by Richard J. Leite, Conrad J. Mason, et.al., University of Michigan, Ann Arbor, Aerospace Engineering, Meteorology and Oceanograph Department, Experiment No. T-030, Final Report, December 1969, 65p. (Contract NAS8-21448), (NASA-CR-109253, Rept. 01747-1-F)

44. New Conclusions Concerning the Observation of Faint Sources from a Sunlit Spacecraft, by Buffalano, C. and W. D. Grobman, Planetary Space Science 17:1089 (1969)

45. Oil-Vapour Contamination of Satellite Optical Surfaces, by T. N. Williams, March 1969, 22p. ref., Royal Aircraft Establishment, Farnborough (Eng.), (RAE-TR-69055)

46. Optical Contamination Due to Outgassing, Teledyne Brown Engineering, Technical Letter SMSD-ABMDA-776, 4 August 1969

47. Outgassing Characteristics of Spacecraft Materials and Physical Adsorption Studies, by G. L. Rao, Teledyne Brown Engineering Summary Report RL-SSL-551, April 1969; ATM Optical Contamination Study

48. Performance and Design Integration Requirements for the Cluster System/Apollo Applications Program, General Specification for NASA/MSFC, Document RS003M00003, 8 August 1969

49. Performance Evaluation of the Celescope Experiment, prepared for NASA-Goddard by SAO Under Contract No. NAS5-1535, NASA-CR-121932

50. Photoheliograph Thermal Vacuum Optical Test Chamber, by R. Hahn, August 12, 1968, 9p., (Contract NAS7-100), (NASA-CR-110248, JPL-750-9)

51. Potential AAP Cluster or Apollo Contamination Monitor in Support of ATM, Martin MCR-68-78 (1968), Martin Marietta Corporation, Denver Division

52. Preliminary Definition of A Contamination Control System for the Sortie Can, Teledyne Brown Engineering Technical Letter ASD-PD-14134, February 2, 1972

53. Proceedings - 8th Annual Technical Meeting and Exhibit, New York, N. Y., May 19-22, 1969, American Association for Contamination Control

54. Procedure for the Determination of Particulate Contamination of Air in Dust Controlled Spaces by the Particle Count Method, SAE ARP 743A

55. Reaction Control System Rocket Engine Space Plume Flow Fields, by B. A. Sodek and C. Y. Chou, Interim Report ATM Optical Contamination Study, RL-SSL-039, Teledyne Brown Engineering, April 1968

56. The Reflectometer Experiment for Application Technology Satellite, Phase 2, Annual Report, November 1, 1967 - January 1, 1969, (Electro-Optical Systems, Inc.) January 1, 1969, pp 87, (NASA-CR-107063)

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-8.3
1. TECHNOLOGY REQUIREMENT (TITLE): Contamination Process Mechanisms; effects vs temp, time, radiation exposure, interactions, production and distribution.	PAGE 10 OF 10

57. Requirements and Constraints for a Space Station Prototype ETC/LSS, SSP Document A8, June 10, 1971

58. Skylab Program Payload Integration Technical Report; Cluster Systems Contamination Analysis Report, Vol. II, Corrective Action Recommendations, ED-2002-879, Vol. II, March 31, 1970

59. Skylab Program Payload Integration Technical Report; Cluster Systems Contamination Analysis Report, Vol. III, Experiment Susceptibility Report, (EREP Supplement), ED-2002-879, Vol. III, EREP Supplement, January 31, 1972

60. Skylab Program Payload Integration Technical Report, AAP Contamination Control Verification and Cluster System Analysis, External Thermal Coating Contamination, ED-2002-879, Vol. IV, March 31, 1970

61. Space Contamination Due to Manned Vehicles, by Kovar, Kovar and Bonner, p. 85, Space Research IX-North-Holland Publishing Company, Amsterdam (1969)

62. Space Measurements of the Contamination of Surfaces by OGO-6 Outgassing and Their Cleaning by Sputtering and Desorption, by D. McKeown and W. E. Corbin, Jr., September 1970, NASA-CR-117138

63. A Survey of Contamination of Spacecraft Surfaces, by C. A. Cothran, et. al., AIAA Paper No. 71-457 presented at the 6th Thermophysics Conference, Tullahoma, Tennessee, April 1971

64. Theoretical Efficiency of the Princeton Two-Element Echelle Spectrograph, by D. A. Markle, et. al., September 1969, 51 p. refs., Prepared for Princeton U. Obs., by Perkin-Elmer Corporation, (Grant NGR-31-001-044), (NASA-CR-115892, ER-9746)

65. Three-Meter Telescope Study Final Report, Perkin-Elmer Corp., Report No. E. R. 10713, Prepared for GSFC, August 1971

66. Vacuum Compatibility of Engineering Materials (Liquid and Sem-Solids), February 1965, NASA TM-X-53207

67. Visual Appearance of Polymeric Contamination; by Harold Shapiro, Washington, June 1970, 15p. ref., NASA-TN-D-5839, G-967.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-8.4

1. TECHNOLOGY REQUIREMENT (TITLE): Contamination Avoidance Devices such as Electrets Contamination Avoidance and Trapping Effectiveness PAGE 1 of 3

2. TECHNOLOGY CATEGORY: Contamination

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop a family of contamination avoidance techniques for application in contamination sensitive payloads.

4. CURRENT STATE OF ART: Very little application of contaminant avoidance devices except for protective covers, pressurization and laminar flow has been applied. HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY: Experience has shown that it is extremely difficult to keep optical surfaces free of particulate and molecular depositions. Even optical components stored for an appreciable length of time will collect considerable amounts of particulate material. Molecular films, particularly pthalates, originating from the HEPA filters also have been observed to deposit on surfaces. Though sensitive surfaces are provided with covers, molecular films and particulates will settle on surrounding surfaces and migrate to the sensitive surfaces after the covers are removed. The degradation in performance from such deposits can render some optical surfaces useless when operated in extreme UV or because of increased light scattering.

A practical method of controlling these particulates and vapors is by trapping them on the surface of an electret. After the mission the electret, which would be in the form of a thin film of polarized dielectric material would be removed and a new electret trapping surface installed. Such trapping surfaces would be located at the aperture of a telescope.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. There has been some work on logic and strategy for employing trapping or protective devices at apertures through which radiation or photon beams pass in order to protect the optics or instruments behind those apertures. Additional effectiveness may be obtained with the development of better trapping devices such as electrets.

b. All Astronomy, x-ray telescope, and solar physics telescopes as well as optical earth observations and oceanographic space experiments will benefit from trapping of contaminants.

c. Payload performance, particularly on sortie observation missions will be enhanced by avoiding deposition of contaminants on optics or on detecting surfaces. Apertures also may be cleared of floating particles if appropriate attracting fields may be applied.

d. Final test is on selected optical telescope payloads on shuttle sortie missions in space.

TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-8.4

1. TECHNOLOGY REQUIREMENT(TITLE): Contamination Avoidance Devices such as Electrets Contamination Avoidance and Trapping Effectiveness

7. TECHNOLOGY OPTIONS:

It is therefore proposed that a research and development program be conducted to determine if electrets can be successfully manufactured in the form of large sheets of polymer materials for use as contamination trapping surfaces by spacecraft. It has been quantitatively demonstrated on a small scale in the laboratory that an electret will trap both particulates and molecular species. The initial effort in this task will determine the best materials for electrets in terms of surface charge retention, life-time, material stability and outgassing characteristics, and particularly methods of manufacturing large sheets or rolls of polarized materials. A parallel effort will determine the efficiency of the electret as a collector of various types of particulates and molecules. Also to be investigated will be the geometry of the electret. Suitable materials with high charge retention capability, very low charge decay rate, high stability, molecular and particulate retention efficiency need to be developed.

8. TECHNICAL PROBLEMS:

a. Initial collection of contamination on trapping surface with subsequent release when surface saturated.

b. Need for electret material to be non-reflective; most effective locations appear to be at interior of sunshade at the entrance aperture of a telescope, with additional protection at the cassegrain telescope output prior to coupling to detectors.

9. POTENTIAL ALTERNATIVES:

a. Complete cleanliness of telescope and spacecraft/carrier vehicle plus protective pressurization with clean inert gas.

b. Covers over telescope/instrument apertures with consequent transmission loss.

c. Same methods may work only on ionized or charged particles.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP 909-54-B, Task 52, Contamination Control with Electrets, R. J. Naumann/E. L. Shriver MSFC, July 9, 1974.

EXPECTED UNPERTURBED LEVEL 3

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Better real time contamination monitors and measurements.

b. Contamination mechanisms/processes understanding.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-8.4

1. TECHNOLOGY REQUIREMENT (TITLE): Contamination Avoidance Devices such as Electrets Contamination Avoidance and Trapping Effectiveness PAGE 3 of 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Theoretical Analysis	—																		
2. Electret Exp. Production		—																	
3. Specimen preparation			—																
4. Test and Analysis			—	—															
5. Reporting				—															
APPLICATION																			
1. Design (Ph. C)				—	—														
2. Devl/Fab (Ph. D)					—	—													
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				T														
NUMBER OF LAUNCHES					26	26	26	26	26	26	26	26	26	26	26	26	26	338

14. REFERENCES:

a. Skylab Induced Environment, R. J. Naumann, MSFC/NASA, Hunstville, Alabama, 1974

b. Space Transportation System Contamination Monitoring Plan, R. J. Naumann, MSFC/NASA, Huntsville, Alabama, About October 1974.

c. Comments from Neil E. Chatterton, Teledyne Brown Engineering, Huntsville, Alabama, December 16, 1974.

Legend:
T = Technology

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED. E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C.9.1

1. TECHNOLOGY REQUIREMENT (TITLE): Instrument Boom, 50 m Extended Alignment, Retractability PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Structural/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED:
To improve alignment accuracy during boom deployment and positioning.
To reduce structural weight.

4. CURRENT STATE OF ART: Laboratory development and demonstration specimens only, not space rated.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY: Development of design concept/materials are needed for extendable/retractable booms which can attain an operational pointing accuracy of 0.5 deg for a duration of 1/2 hour, and a stability level of 0.1 deg for a duration of 1/2 hour with a maximum stability rate of 0.1 deg/sec. An additional objective is to minimize structural weight. Current state of the art is somewhat deficient in providing required pointing stability. A load up to 60 kg should be deployed away from spacecraft, preferably beyond most of the contamination zone. Structural concepts amenable to extended lengths up to 100 m with minimal weight and stowage-volume penalties are desirable.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. The critical pointing parameters have been initially selected equal to the pointing requirements of the Shuttle.

b. The benefitting payloads: AP06S, "Atmospheric, Magnetospheric, and Plasmas in Space (AMPS)", ST-21-S "XST-017 Upper Atmospheric Neutral Gas Parameters", ST-22-S "XST-014 Spacecraft Wake Dynamics and XST-029 Environmental Effects on Non Metals", ST-23-S "XST-001 Microwave Interferometer", and ST-32-S "Wall-less Chemistry Facility".

c. The presence of optical equipment and magnetic and electric field sensors mounted on the remote platform at the boom's end calls for high pointing accuracy to obtain reliable experiment results. The retractability of the boom is imposed by the requirement of retrieving space hardware.

d. This technology requirement will be satisfied when a breadboard instrument boom is tested in relevant load and thermal environment in the laboratory.

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TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C.9.1

1. TECHNOLOGY REQUIREMENT(TITLE): Instrument Boom, 50 m Extended Alignment, Retractability PAGE 2 OF 3

7. TECHNOLOGY OPTIONS: A matrix of structural materials and design concepts are considered and evaluated including tubular, furlable, articulated, foldable, etc. Critical parameters are associated with susceptibility of design concepts and materials to uneven heating under solar radiation, the resulting distortions, and possible instabilities. Parameters involved in trades include load carried, boom length extended, boom length retracted, extension and retraction time, resonant frequency, articulation angle range, articulation angular velocity, base gimbal characteristics as well as line of site pointing accuracy and stability. The size and mass distribution of the "payload" carried on the boom also affects boom characteristics. Gravity gradients, atmospheric drag as a function of altitude need to be investigated.

8. TECHNICAL PROBLEMS:

a. The retractability requirement may impose weight and cost penalties in the development of the new technology items. Power requirements will be larger than for extendable only systems.
b. In low earth orbit such as 435 to 340 km, considerable air drag and gravity gradient effects are experienced, tending to deflect the boom.
c. Electrical conductivity (an isolated or non-conducting boom is desirable).

9. POTENTIAL ALTERNATIVES:

a. Remote maneuverable Vehicle/Teleoperator flying in same orbit ahead of shuttle orbiter (retractible by maneuver).
b. Use a less rigid (and lighter) boom complemented with additional optical alignment equipment such as a laser beam reflecting from a corner reflector on the payload end of the boom, with error signals being detected at a directional sensor located at the gimballed base mount; active correction of boom deflections can be provided via existing servos. Protective thermal control coatings would be employed. There is possibility of lowering boom system weight and cost.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

TBD

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

New material developments, including composites and combinations of metallics and composites may ease meeting the stated operational pointing accuracy and stability requirements with lower structural weights.

Rev. 11/15/74

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C.9.1

1. TECHNOLOGY REQUIREMENT (TITLE): Instrument Boom, 50 m Extended Alignment, Retractability — PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Ops. & Param. Analysis																			
2. Model Design																			
3. Build Model																			
4. Test Model																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations							•	•	•	•••	•••	••••	•••	••••	•••	••••	•••		
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					T													
NUMBER OF LAUNCHES							1	1	1	3	3	4	3	4	3	4	3	30

14. REFERENCES:

a. Summarized NASA Payload Descriptions, Sortie Payloads, Level A Data, NASA PD, July 1974.

b. Preliminary Payload Descriptions, Volume II, Sortie Payloads, NASA, July 1974, AP-06-S, Atmospheric, Magnetospheric, and Plasma (Experiments) in Space (AMPS), pages 4-1 to 4-101.

Legend

- • Sortie operations
- T Technology

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C.9.2

1. TECHNOLOGY REQUIREMENT (TITLE): Payload and Spacecraft Structure, Tower (SS001); light weight fabrication PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Structural/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop light weight structural concepts/ materials and low-cost manufacturing techniques for payloads and spacecraft.

4. CURRENT STATE OF ART: Present material and fabrication technology needs refinement to achieve lightweight goals that will permit orbiting of larger spectrum of spectrum of satellites at synchronous orbit. HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Development of an ad hoc lightweight structure is required to satisfy the needs of satellite CN-54A and relieve TUG payload capability limitations. The critical parameters is structural weight (86.2 Kg) with consideration for low-cost fabrication techniques.

The study documented in Ref. a. evaluated a thin-gage magnesium tubing structure and provides a reference point design.

For large area structures such as antennas and arrays, compactly stowed deployable structures are needed at lower cost than currently available.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. The limitations of the TUG payload capability make the tower's weight the critical parameter. The design evaluated in reference a. is of a preliminary nature, and other structural concepts and materials must be considered and evaluated.
b. The initial benefiting payload is CN-54A, "Disaster Warning Satellite" and other geosynch payloads. However, light weight low cost fabrication is applicable to all payloads, both sortie and automated.
c. A direct trade of payload weight versus tower structural weight is the potential benefit of this development to overcome limits of TUG payload capabilities and expand the spectrum of satellites that can be placed on synchronous orbit.
d. When a breadboard tower structure is tested under simulated load, thermal, and space environment, this technology requirement will be satisfied. Other lightweight, larger structures such as antennas may need testing in the space environment as well as in the laboratory on the ground.

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TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. C.9.2

1. TECHNOLOGY REQUIREMENT(TITLE): Spacecraft Structure, Tower (SS001); light weight fabrication — PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

Low structural weight fractions can be achieved by the use of composite materials, machined thin wall metallics, and sandwich trusses. A comparative study should be done of weight tradeoffs of several concept/fabrication techniques. The most promising material for lightweight, high stiffness, and low expansion are the graphite epoxy advanced composites. To take advantage of the low expansion characteristics of the graphite, the material should be fabricated as a lay-up using continuous fibers. The lay-up orientations should be varied through 0^{o} at least $\pm 45^{o}$ and 90^{o} directions of fiber to obtain a given isotropic structure. Such materials are operable to 350^{o}F, if higher temperatures are required, the matrix polymer can be changed to polyamide to allow operating temperatures up to 550^{o}F.

8. TECHNICAL PROBLEMS:

A potential problem area associated with the development of this structure is the fabrication of thin gage metallic and composite members.

Original low cost techniques, studied by Lockheed, took advantage of higher Shuttle payload capabilities to show that higher weight allowances would produce lower costs. However, there is an advantage in large structures to lower weight and costs.

9. POTENTIAL ALTERNATIVES:

a. Use other materials such as composite, beryllium and aluminum.
b. Use a trussed tower with thin-gage sandwich (perforated core) members.
c. Use a thin-gage stiffened shell of similar materials.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

W74-70278 (502-22-10), Advanced Space Structures, Langley Research Center, George W. Brooks, (703) 827-2042.

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

Development of lightweight, spaced rated, structures.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C.9.2

1. TECHNOLOGY REQUIREMENT (TITLE): Spacecraft Structure Tower (SS001); light weight fabrication PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Ops & Param. Analysis																			
2. Model Design																			
3. Build Model																			
4. Test Model																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					T													
NUMBER OF LAUNCHES							T1	T1			T1					T1		4

14. REFERENCES:

a. Disaster Warning Satellite Study, Report TMX-68122 NASA/LeRC, Spacecraft Technology Division, March 1971.

b. Summarized NASA Payload Descriptions, Automated Payloads, July 1974, NASA/MSFC, p. 164.

Legend

T: Technology

— Automated Operations

T1 = CN-54-A, Disaster Warning Satellite

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

C. 4

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-9.3

1. TECHNOLOGY REQUIREMENT (TITLE): Protective Shell/Cover PAGE 1 OF 5
Reduction of high energy loss and secondary radiation; improved thermal control

2. TECHNOLOGY CATEGORY: Structural/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop a contamination and thermal protection cover which minimizes environmental control costs, energy losses and secondary radiation.

4. CURRENT STATE OF ART: Current state of the art heat shields do not have the capability to pass gamma rays and cosmic rays above one GeV without some secondary reactions.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Protective shells up to 4.27m dia and 7.3m long are needed to provide thermal and pressurization for some high energy payloads. The protective shell is desired to hold the payload temperature at a selected temperature within a 263 to 303°K range up to $\pm 2^{\circ}$K. The shell will also enable internal cleanliness up to 1000 class pressurization up to 110000 N/m^2 (one atmosphere), and enable venting and pressurization control to ± 0.1 atmosphere. The shell shall pass gamma and cosmic rays with minimum loss and secondary radiation (loss less than 0.1% at 1 MeV. Typical radiation length used to date for lower energy cosmic rays is ≤ 1 gm/cm^2 for shell thickness. Some experiments may require a thinner window, particularly in the lower energy gamma ray range.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Some of the high energy payloads operate better in a pressurized atmosphere with adequate thermal isolation. A protective shell and the beneficial environment will not seriously detract from performance but allows considerable cost savings.
b. The benefitting payloads are: HE-01-A, HE-03-A, HE-08-A, HE-09-A, HE-11-A, HE-12-A, and HE-15-S, "High Energy Astrophysics."
c. Enables control and rejection of interfering heat loads and particles at low energies (up to 1.0 MeV) with minimum secondaries and persistent radioactivity.
d. When a full scale model has operated in a space equivalent environment passing gamma and cosmic rays with low loss (<0.1%) and uniformly to an internal gamma ray or cosmic ray instrument, technology requirement will be satisfied.
An Atlas/Centaur could be used as the booster for the test.

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TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-9.3

1. TECHNOLOGY REQUIREMENT(TITLE): Protective Shell/Cover PAGE 2 OF 5

Reduction of high energy loss and secondary radiation; improved thermal control

7. TECHNOLOGY OPTIONS:

Use of basic shell materials with atomic number below 20 include:

a. Beryllium (Z = 4)
b. Magnesium (Z = 12)
c. Aluminum (Z = 13)

Choice of external high reflecting, mission coatings as well as basic thermal equalization material or process gives a large number of options to be investigated. The need for uniform cross section makes it difficult to utilize heat pipes for thermal equalization.

8. TECHNICAL PROBLEMS:

a. Removal of excess heat generated by inside equipment while protecting large payloads from external heating effects.
b. Minimizing secondary radiation (gamma, X rays, particles) at lower energies while enabling passage of gamma rays and cosmis rays >1 MeV.

9. POTENTIAL ALTERNATIVES:

a. Build gamma ray and cosmic ray instruments to withstand and provide their own thermal control at much greater cost.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

(TBD)

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Thermal control, structures, and materials technologies need to cooperate in solving the protective shell problem.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-9.3

1. TECHNOLOGY REQUIREMENT (TITLE): Protective Shell/Cover PAGE 3 OF 5

Reduction of high energy loss and secondary radiation; improved thermal control

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Ops & Param. Analysis																			
2. Model Design																			
3. Build Model																			
4. Test Model																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations						T7 •			T2 •					T1 •			T3		
4.					T4				T5			T6				T5			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				T														
NUMBER OF LAUNCHES						2		1	2			2	1	1			1	10

14. REFERENCES:

a. Final Report of the Space Shuttle Payload Planning Working Groups, High Energy Astrophysics, May 1973, Goddard Space Flight Center.
b. Materials for Radiation Detection, Jan. 1974, National Materials Advisory Board.
c. Summarized NASA Payload Descriptions, Sortie Payloads, July 1974, NASA/MSFC.

Legend

T1 = HE-01-A, Large X-Ray Telescope Facility
T2 = HE-03-A, Extended X-Ray Survey
T3 = HE-08-A, Large High Energy Observatory A
T4 = HE-09-A, Large High Energy Observatory B
T5 = HE-11-A, Large High Energy Observatory D
T6 = HE-12-A, Cosmic Ray Laboratory
T7 = HE-15-S, Magnetic Spectrometer
• Sortie operations
— Automated operations
T Technology

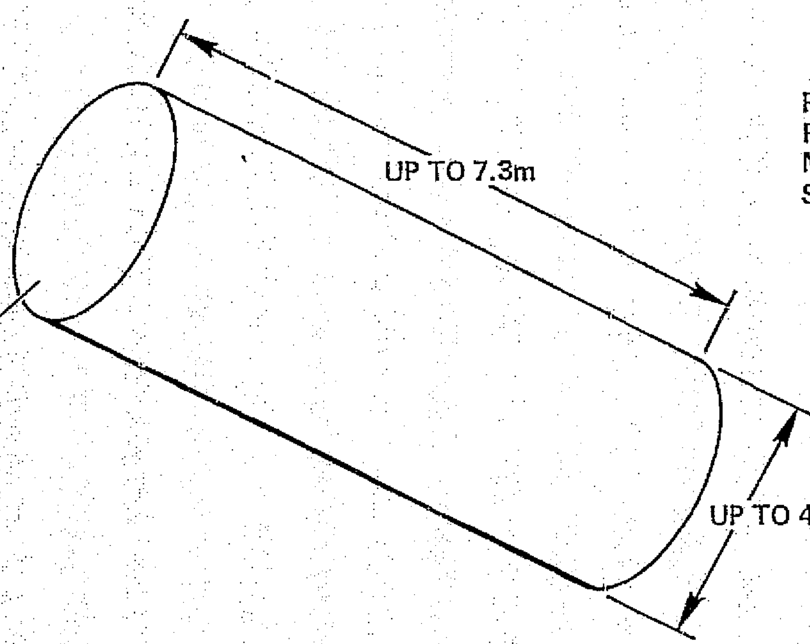
15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

Protective Shell

GAMMA & COSMIC RAY SORTIES & AUTOMATED PAYLOADS

MISSION REQUIREMENTS		STRUCTURAL/MECH. REQUIREMENT
PROVIDE UNIVERSAL THERMAL CONTROL/PRESSURE CONTROL SHELL TO MINIMIZE ENVIRONMENTAL CONTROL COSTS	⇨	HOLD INTERNAL PAYLOAD TEMPERATURE TO ±2K (263 TO 303K RANGE, FOR 7,000-kg MAX PAYLOAD) WITH NO GAMMA/COSMIC RAY DEGRADATION



PASS GAMMA & COSMIC RAYS > 1 MeV WITH MINIMUM LOSS & SECONDARY RADIATION

END COVER OPENS TO ADMIT GAMMA & COSMIC RAYS < 1 MeV FOR PAYLOADS IN LOWER ENERGY RANGES

Protective Shell

ITEM	CAPABILITY REQUIRED	STATE OF ART
TEMPERATURE CONTROL; (K) (RANGE)	±2K OF SELECTED TEMP (263 TO 303K)	±10K OF SELECTED TEMPERATURE
GAMMA RAY LOSS AT 1 MeV	< 1%	< 5%
SECONDARY RADIATION (%)	<0.1%	1%
INTERNAL ATMOSPHERE CLEANLINESS CLASS	1,000	10,000

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C.8.4

1. TECHNOLOGY REQUIREMENT (TITLE): Metering Structure for Solar Telescopes; Decrease dimensional sensitivity to thermal variations PAGE 1 OF 5

2. TECHNOLOGY CATEGORY: Structural/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: Decrease dimensional sensitivity to thermal variations. Obtain at least a 0.15 (preferably 0.075) arc second resolution (a measure of mirror figure contour accuracy & metering structure stability).

4. CURRENT STATE OF ART: The Skylab ATM Hα instrument could have a pointing error up to 1 arc second due to thermal gradients. Normal temperature range for operating was ± 9.5°K. HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY Truss-type and shell-type structures having zero expansion coefficient characteristics are needed to satisfy the resolution requirements of equipment mounted on it. Near zero-expansion graphite-epoxy composite materials with or without metallic straps offer the potential needed for this application. Critical parameters are a pointing accuracy of 10 arc sec for a duration of .83 hr, a stability of .15 arc sec for a duration of 3.8E-04 hour, a stability rate of .15 arc sec/sec, and a spatial resolution of 0.15 arc sec (preferably 0.075 arc sec). However, the metering structure is interdependent with the telescope mirrors.

The solar telescope mirrors suffer the most from heat loading and temperature rise. Use of temperature insensitive substrates with a fused silica surface and high reflectivity coatings should be considered. Three sizes of photoheliograph telescopes are being considered (65 cm early, 100 cm later, and finally 150 cm diameter). Ultimately the 150 cm photoheliograph axis will be directed by advanced offset star trackers and/or a pattern recognition tracker to selected objects with an accuracy of 0.1 arc sec.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. The critical parameter is the temperature control of the mirror within $\Delta t = 9.3$ K at 293°K. The problem is compounded by high f number (f/40) resulting in focal length of 200-300 cm, which must be folded to maintain reasonable barrel dimensions. Thermal distortions could degrade the system resolution.

b. The benefitting payloads are SO-01-S Dedicated Solar Sortie Mission (DSSM), SO-11-S Solar Fine Pointing Payload, and SO-02-A Large Solar Observatory.

c. Smaller primary held at $\Delta t = 9.3$°K would have less thermal distortions and result in ability to resolve smaller details.

d. This technology requirement will be satisfied when a breadboard structure is tested in relevant environment in the laboratory.

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TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C.9.4

1. TECHNOLOGY REQUIREMENT(TITLE): Metering Structure for Solar Telescopes; Decrease dimensional sensitivity to thermal variations

7. TECHNOLOGY OPTIONS: Optional materials and design concepts such as Invar and compensating composite/metallic elements could be possibly used but they do not offer the potentials of the near zero-expansion graphite-epoxy structures.

8. TECHNICAL PROBLEMS: a. A potential problem exists in the calibration of structure after manufacture which must be done to identify actual characteristics of the structure which vary due to material property scatter. The difficulty consists in performing accurate measurements under laboratory conditions simulative of spatial environment.
b. Obtain $1/20\lambda$ in the spectral range from 90 nm to 900 nm versus solar light/dark cycle thermal changes. The primary, secondary, and coupling optics may need to be made of materials with low temperature coefficients of expansion as well as the metering structure.

9. POTENTIAL ALTERNATIVES:

a. Compensating composite/metallic structural concepts offer some possibility but they are sensitive to actual temperatures which could be different than predicted/design temperatures.
b. Use of high reflective coatings and more efficient heat dump mirrors will help reduce optics temperature excursions.
c. Use of predictable materials and improved active thermal control system.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. NAS8-28201 "Graphite-Epoxy Metering Shell (GEMS)". Contract from NASA MSFC to General Dynamics Convair. (See pages 4 and 5.)
b. NAS8-29825 "Design, Fabrication, and Test of a Graphite-Epoxy Metering Truss". Contract from NASA MSFC to the Boeing Co.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Development of mirror substrates and coatings insensitive to thermal distortions.
b. Large Space Telescope development spinoff.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-9.4

1. TECHNOLOGY REQUIREMENT (TITLE): Metering Structure for Solar Telescopes; Decrease dimensional sensitivity to thermal variations

PAGE 3 OF 5

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Ops & Param. Analysis																			
2. Model Design																			
3. Build Model																			
4. Test Model																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations					T1	•	•	•	••	•• T2	••••	••	•••	••	•••	••	•••		
4.					T3	•	•	•	•	•									

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE			T															
NUMBER OF LAUNCHES						2	2	2	3	3	5	2	3	2	3	2	3	32

14. REFERENCES:

a. Summarized NASA Payload Descriptions, Automated Payloads, July 1974, NASA/MSFC, p. 60.

b. Summarized NASA Payload Descriptions, Sortie Payloads, July 1974, NASA/MSFC, pp. 120, 122.

c. Photoheliograph Definition Study, Volume II, Book II, 100-Centimeter Photoheliograph for Shuttle and Balloon Missions, NASA Contract NAS 8-28147, Itek Optical Systems Division.

Legend

- • Sortie Operations
- — Automated Operations
- T: Technology

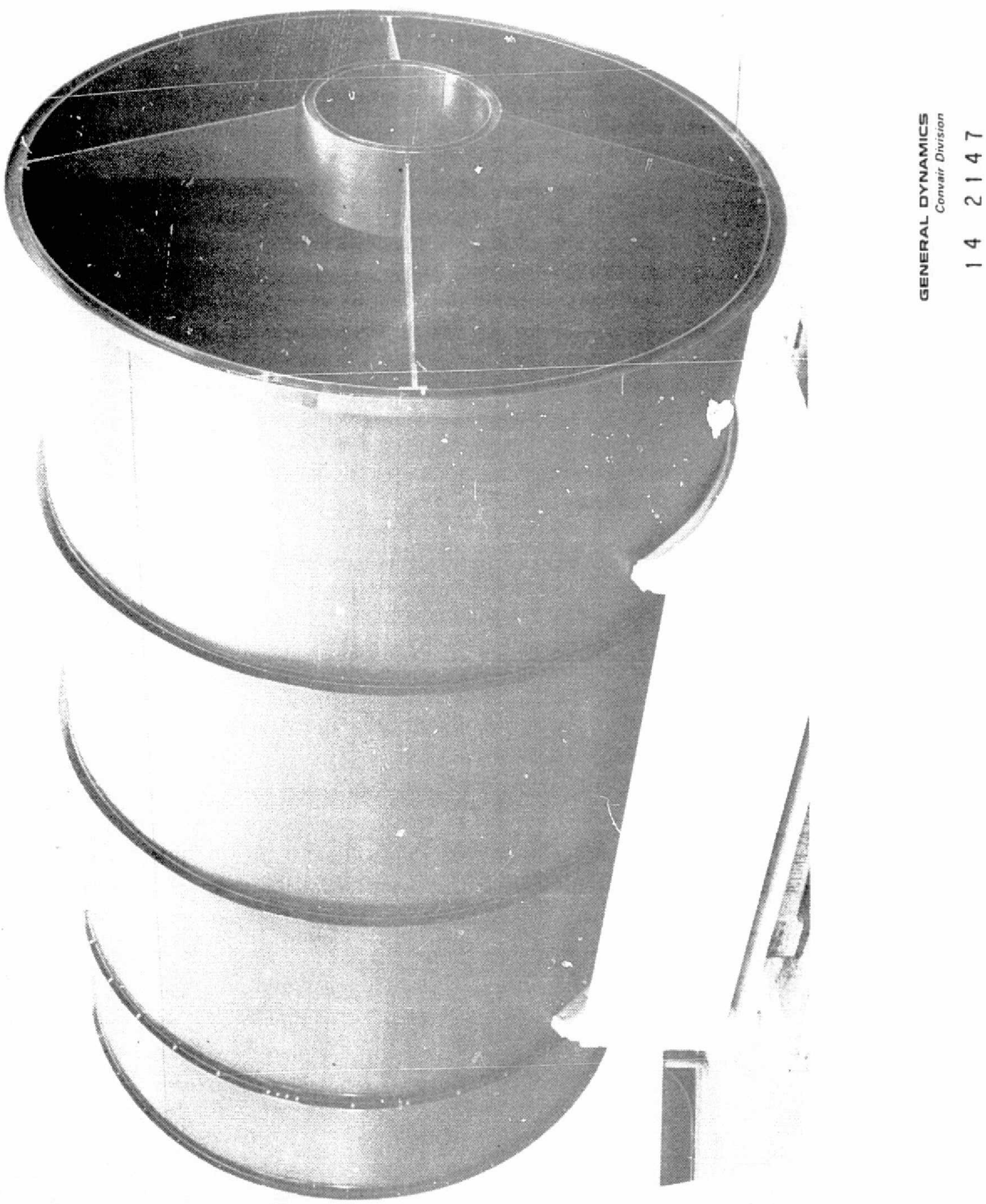
T1 = SO-01-S, Didicated Solar Sortie Mission (DSSM)
T2 = SO-02-A, Larger Solar Observatory
T3 = SO-11-S, Solar Fine-Pointing Payload

15. LEVEL OF STATE OF ART

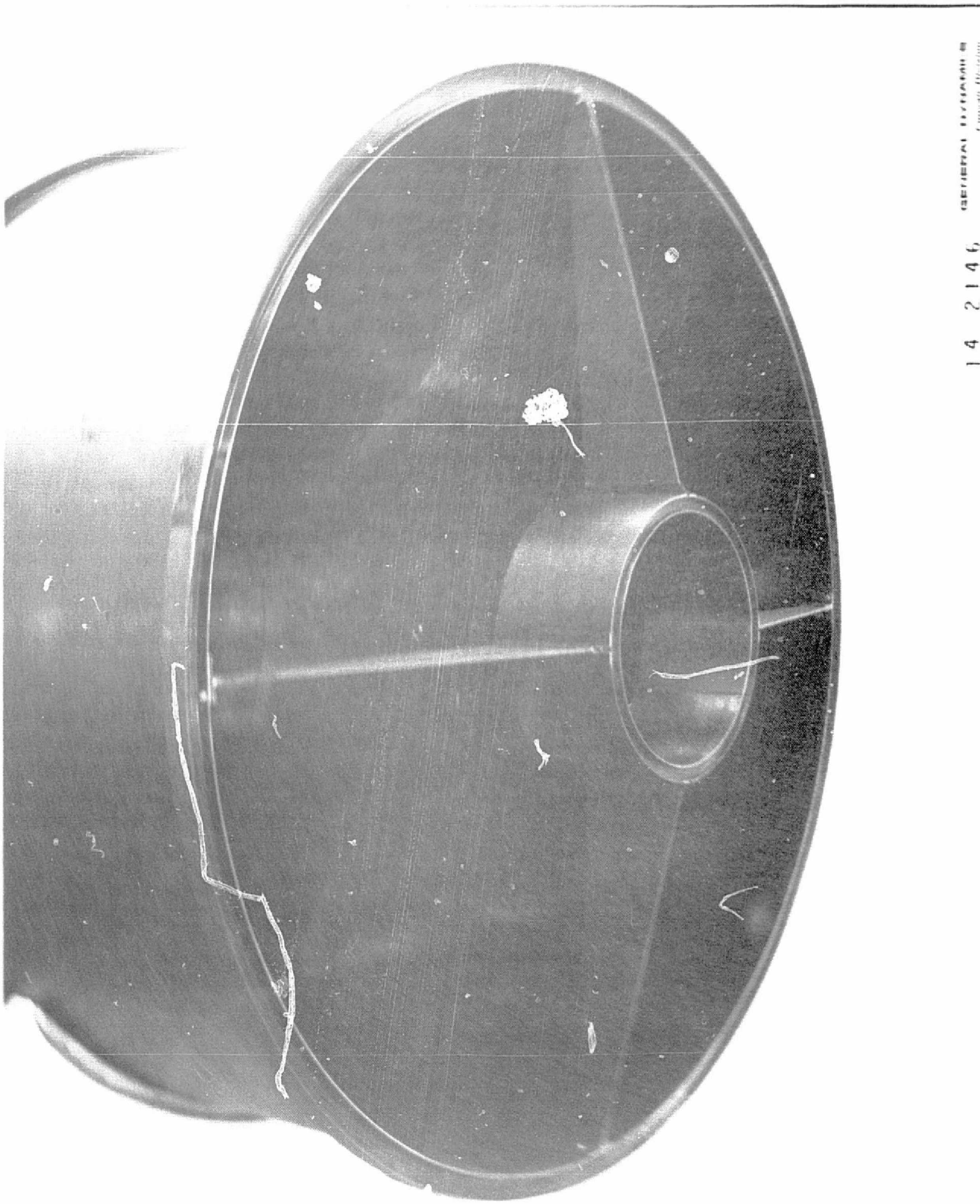
1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. C-9.4

1. TECHNOLOGY REQUIREMENT (TITLE): Metering Structure for Solar Telescopes; Decrease dimensional sensitivity to thermal variations — PAGE 4 OF 5



PAGE 1 OF 1



DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-9.5

1. TECHNOLOGY REQUIREMENT (TITLE): Entry Probe PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Structural/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop entry probe heat shield capable of planetary entry with larger ΔV environment.

4. CURRENT STATE OF ART: Apollo used heat shield, but some planetary missions will have a ΔV larger than the existing thermal shield on Apollo CM.

HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY

Blunt body heat shield technology should be developed to withstand the entry heating environments of Saturn, Uranus and Jupiter which have peak rates of approximately 20, 7, and 75 kW/cm^2. Low heat shield fractions are required in order to increase the size of the payload packages. A single entry probe for both Saturn and Uranus may prove economical, while a special one for Jupiter would be required. Ablative/reflecting dielectric heat shield concepts offer potential superior to those of conventional heat-shield concepts.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Heat shield mass fractions from .10 to .46 are required to satisfy the entry requirements. These fractions should be lowered to permit larger payloads.
b. The benefitting payloads are: PL-11-A "Pioneer Saturn/Uranus Flyby," PL-13-A "Pioneer Jupiter Probe," and PL-22-A "Pioneer Saturn Probe."
c. This technology is required to perform atmospheric measurements of Uranus, Saturn and Jupiter.
d. This technology requirement will be satisfied with model testing in actual space environment, most likely on some high density planet.

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TO BE CARRIED TO LEVEL 8

1. TECHNOLOGY REQUIREMENT(TITLE): Entry Probe

7. TECHNOLOGY OPTIONS:

Alternate ablative materials such as opaque sublimers (e.g., carbon-phenolic, graphite) can be used although with decreased performance. Radiative heat shield concepts may offer some possibilities particularly if minimum foreign material is desired in the region of probe measurements.

8. TECHNICAL PROBLEMS:

a. Validity of ablative analyses at high heating rates
b. Sensitivity of analysis to atmospheric composition, radiation blockade and sublimation chemistry. Heat shield configurations that reduce the possibility of turbulent flow
c. Scaling of time for testing purposes
d. Reliability of components in radiation environment

9. POTENTIAL ALTERNATIVES:

Radiative heat shields plus insulation protective layer are a possibility although there may be interference with measurements.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. W74-70253 (502-21-20), Advanced Materials for Space, Lewis Research Center, W. D. Klopp, (216) 433-6676.
b. W74-70331 (502-07-01), Gas Dynamics Research, Langley Research Center, Eugene S. Love, (703) 827-2893.
c. Martin Contract with NASA ARC.
d. Mc DAC Contract with NASA ARC.

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

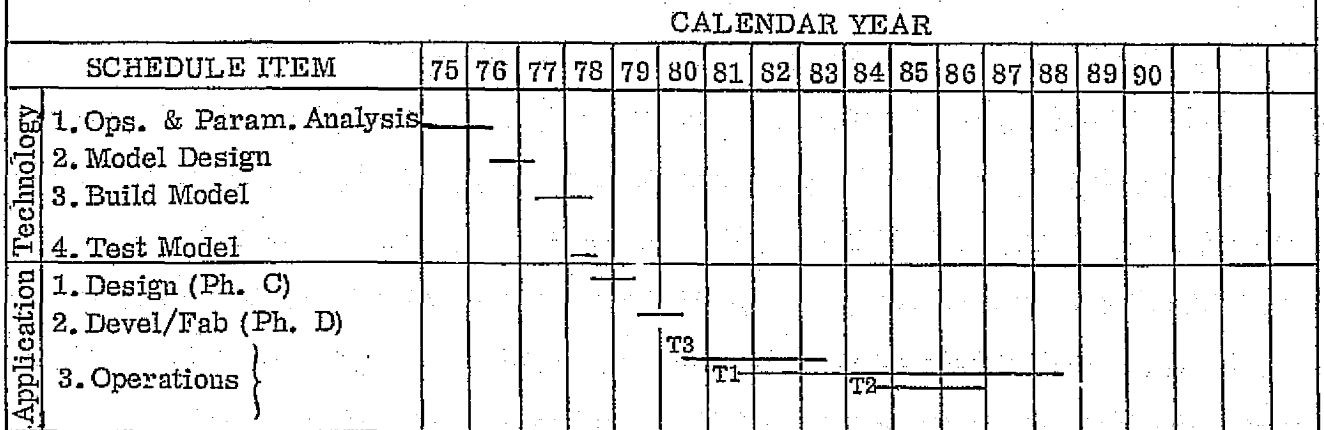
a. Insulation between heat shield and probe instruments,

DEFINITION OF TECHNOLOGY REQUIREMENT

NO. C-9.5

1. TECHNOLOGY REQUIREMENT (TITLE): Entry Probe PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:



13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
TECHNOLOGY NEED DATE				T													
NUMBER OF LAUNCHES						1	1			2							4

14. REFERENCES:

See Page 4 for References.

Legend:

T1 = PL-11-A, Pioneer Saturn/Uranus Flyby
T2 = PL-13-A, Pioneer Jupiter Probe
T3 = PL-22-A, Pioneer Saturn Probe
T = Technology
—— Automated operations

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

1. TECHNOLOGY REQUIREMENT (TITLE): Entry Probe

14. REFERENCES:

a. The Outer Solar System, Volume 29, Part 2, Proceedings of the AAS 17th Annual Meeting, p. 215-
b. Summarized NASA Payload Descriptions, Automated Payloads, July 1974, NASA/MSFC.
c. "Atmospheric Entry Probes for Outer Planet Exploration - A Technical Review and Summary," NASA CR 137542, by Dynatrend Inc., August 1974.
d. "Proceedings - Outer Planet Probe Technology Workshop - Summary Volume," Workshop held at Ames May 21-23, 1974. NASA CR 137543, by Dynatrend Inc.
e. "Saturn/Uranus Atmospheric Entry Probe," Final Report, by McDonnell Douglas Corp, July 18, 1973.
   Part I: Summary. MDC E0870.
   Part II: Technical Discussion. MDC E0870.
f. "Jupiter Atmospheric Entry Probe," NASA Ames, September 1974.
g. "Outer Planet Probe Entry Thermal Protection,"
   Part I: "Aerothermodynamic Environment," by Nicolet, Morse, Vogvodich, AIAA Paper No. 74-700, July 1974.
   Part II: "Heat-Shielding Requirements," by Nicolet, Howe, Mezines, AIAA Paper No. 74-701, July 1974
h. "Sensitivity of Probe Heating Environment to Entry Parameters," by NASA Ames - Advanced Space Projects Office, September 1974.
i. "Outer Planet Atmospheric Entry Probes," by McDonnell Douglas Corp., May 1974. (Booklet)

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-9.6

1. TECHNOLOGY REQUIREMENT (TITLE): Instrument Mount/Selector PAGE 1 OF 3
Reduction of dimensional and angular degradation

2. TECHNOLOGY CATEGORY: Structural/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: To increase dimensional stability of instrument mount under space environment. Enable vernier rotation, tilt, cross axis, and axial measurements to one arc sec and 1 micrometer

4. CURRENT STATE OF ART: Most of space X-ray instruments are mounted one at a time at the focal point in a fixed mount which makes it difficult to move instruments in sequence to the least distortion field of the X-ray telescope.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

To develop an instrument mount having high dimensional stability in order to avoid large variations or interference with images, polarization measurements and detailed spectral measurements. This dimensional stability is required under various conditions of vibration, temperature, and aging. The use of zero-expansion graphite epoxy material offers the potential required for thermal stability.

Capability: The instrument mount selector assembly mounts 5 instruments, a field monitor, and guide star tracker. The mechanism of the mount moves one of 5 scientific instruments into X-ray field of view, angle adjustable to one arc second and translations to 1 micrometer crosswise and axially with respect to the line of sight.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. The mount dimensional stability to better than 0.5 arc sec is required for the temperature range of 270-275°K under operating conditions, and have a cleanliness class of 1000.
b. The benefiting payloads are HE-01-A, Large X-Ray Telescope Facility, HE-11-A, Large High Energy Observatory D, HE-20-S, High Resolution X-Ray Telescope. The techniques would also improve XUV, UV, visible light, and IR telescope selectors.
c. Enables use of more than one instrument per telescope to maximize X-ray telescope mission output and scientific return with minimum dimensional degradation penalty. Due to the relatively short wavelength of X-rays within the X-ray telescope spectral range, small variations in dimensional stability cause large variations in images, polarization measurements, and detailed spectral measurements.
d. This technology requirement will be satisfied when a breadboard mount/selector is tested in relevant environment in the laboratory.

TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. C-9.6

1. TECHNOLOGY REQUIREMENT(TITLE): Instrument Mount/Selector — PAGE 2 OF 3

Reduction of dimensional and angular degradation.

7. TECHNOLOGY OPTIONS:

a. Compensating metallic/composite structural concepts
b. Low expansion coefficient materials.
c. A rotating "Lazy Susan" type of instrument selector as well as sliding rail type concepts have been studied. The alternative mechanisms will enable rotation or translation of one instrument at a time in to X-ray mirror focal position, as well as providing vernier adjustments in rotation around the line of sight, tilt, cross axis, and axial vernier adjustments.

8. TECHNICAL PROBLEMS:

a. Design, fabrication of a low distortion mount, and calibration under laboratory conditions simulating space environment.
b. Flexability in shifting one of 5 X-ray instruments into X-ray telescope field without distorting visible light/UV field monitor and guide star trackers.

9. POTENTIAL ALTERNATIVES:

(TBD)

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. W74-70635 (188-41-64), X-Ray Spectroscopy for Shuttle, NASA/GSFC, Elihu A. Boldt, (301) 982-5853.
b. W74-70631 (188-41-59) X-Ray Astronomy, NASA, Washington, D. C., N. G. Roman, (202) 755-3649.
c. Conf. S. S. Holt with E. S. Saari, 6 November 1974 at GSFC.

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

Development of light weight, zero-expansion graphite epoxy materials.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. C-9.6

1. TECHNOLOGY REQUIREMENT (TITLE): Instrument Mount/Selector — PAGE 3 OF 3

Reduction of dimensional and angular degradation

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Ops & Param. Analysis		—																	
2. Model Design			—	—															
3. Build Model				—															
4. Test Model					—														
5.																			
APPLICATION																			
1. Design (Ph. C)					—	—													
2. Devl/Fab (Ph. D)						—	—												
3. Operations							T3	• T2	—	• —	T1 —	— —	— —	—	—	—	—	—	—
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					T					T								
NUMBER OF LAUNCHES								T3	T2	T3		T1					T2	5

14. REFERENCES:

a. Final Report of Space Shuttle Payload Planning Working Groups, NASA/GSFC, May 1973, pages A-1, -2, -4.
b. Summarized NASA Payload Descriptions, Sortie Payloads, PD, NASA, July 1974, pages 112-115.
c. Summarized NASA Payload Descriptions, Automated Payloads, Level A Data, July 1974.
d. Payload Descriptions, Vol. I, Automated Payloads, Level B Data, NASA, July 1974.

Legend

T1 = HE-01-A, Large X-Ray Telescope Facility
T2 = HE-11-A, Large High Energy Observatory D (1.2m X-Ray Telescope)
T3 = HE-20-S, High Resolution X-Ray Telescope
T = Technology
— = Automated
• = Sortie

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. C-9.7

1. TECHNOLOGY REQUIREMENT (TITLE): Module Resupply Mechanism — PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Spacecraft/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: To resupply and refurbish a spacecraft in orbit.

4. CURRENT STATE OF ART: Engineering hardware has been built and feasibility of concepts is being tested for Shuttle Orbiter based systems.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Malfunctioning or depleted spacecraft systems can be replaced, remotely, in orbit without having to return the entire spacecraft to earth for refurbishment or rework. The initial system is configured for use with the Shuttle Orbiter. Advanced indexer manipulator systems concepts are being considered for use on a retrievable Tug in synchronous or higher orbits.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) The present method for orbiting a spacecraft precludes its recovery for repair or refurbishment. The cost effective solution is to provide systems to recover, repair, and re-orbit spacecraft.

(b) EOS-A*, B, C, and D; SMM; EGRET; SSOS; SEOS; SeaSAT** will benefit. LS-02-A, Biomedical Experiment Scientific Satellite (BESS) could benefit if means is provided for continuous life support for specimens during modular unit replacement operations. Additional operational synchronous orbit spacecraft such as EO-58-A (GOES), EO-59-A(GEOS) or their replacements could benefit. AS-16-A, Large Radio Observatory Array, is currently scheduled as a typical example for remotely controlled servicing at greater than synchronous orbit altitudes.

(c) In orbit repair and refurbishment of spacecraft will replace the present method of operations, i.e., launching a second or back-up spacecraft to complete the mission of the malfunctioning spacecraft.

(d) The test of a model with a spacecraft to demonstrate its applicability will satisfy this technology requirement.

*EO-08A

**OP-07-A & -09A

TO BE CARRIED TO LEVEL 7

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DEFINITION OF TECHNOLOGY REQUIREMENT

NO. C-9.7

1. TECHNOLOGY REQUIREMENT(TITLE): Module Resupply Mechanism

7. TECHNOLOGY OPTIONS:

(a) Development of an EVA and/or Shuttle attached manipulator system for refurbishment and repair of malfunctioning spacecraft systems.

(b) Capture and return spacecraft to earth for refurbishment and/or repair.

(c) Continue present mode of operation, i.e., that of replacing the total spacecraft.

8. TECHNICAL PROBLEMS:

(a) Timely installation and alignment of mechanism in orbiter during turnaround operations of orbiter.

(b) Weight reduction of module resupply mechanism.

(c) Effect of thermal gradients on alignment of spacecraft/resupply mechanism interface.

9. POTENTIAL ALTERNATIVES:

There are no known potential alternatives other than those discussed in Section 7.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

(a) EGRET spacecraft, F. J. Cepollina, (301) 982-5913.

(b) RTOP W74-70824 (970-63-10), Teleoperator Control and Manipulation, W. G. Thornton, MSFC, Huntsville, Ala., (Ph. 205-453-5530).

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

Development of composite material mechanism to solve weight and thermal gradient problems.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-9.7

1. TECHNOLOGY REQUIREMENT (TITLE): Module Resupply Mechanism

PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Redesign E/U																			
2. Modification E/U																			
3. Qualification E/U																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				△														
NUMBER OF LAUNCHES					2	2	1	2	1	*	1	*	*	1	*	*	*	9

14. REFERENCES:

a. Flight Support System for Earth Observation Satellites (NAS5-23203, Mod 4) SD74-SA-0057

b. Letter: NASA/GSFC File No. 8213, Code 730, Subject: "Study of Future Payload Technology Requirements, Contract NAS 2-8272", F. J. Cepollina to H. M. Ikerd, GD/Convair, dated 10 January 1975.

c. In-Orbit Servicing by Frank J. Cepollina and James Mansfield, pages 46-56 Astronautics & Aeronautics, Vol. 13, No. 2, dated February 1975.

d. MCR-73-337, NAS 8-29904, Final Report, Shuttle Remote Manned Systems Requirements Analyses, prepared for MSFC by Martin Marietta Corporation, February 1974.

Legend – * Resupply Missions
E/U Engineering Unit

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-9.8

1. TECHNOLOGY REQUIREMENT (TITLE): Spacecraft Docking/ Deployment (Latching) and Retention Mechanisms PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Spacecraft/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: To launch or retrieve a spacecraft or to resupply and refurbish a spacecraft while in earth orbit. Technique should work in low, synchronous, or greater orbits accessible by Shuttle Orbiter or Tug.

4. CURRENT STATE OF ART: Preliminary design concepts.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

(a) Malfunctioning or depleted subsystems/instruments can be replaced, remotely, with the spacecraft docked to the Shuttle Orbiter or Tug while in orbit without having to return the entire spacecraft to earth for refurbishment or rework.

(b) Spacecraft may be launched by the Shuttle/Tug.

(c) Spacecraft launched prior to the Shuttle era may be retrieved by the Shuttle and returned to earth.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) The present method for orbiting a spacecraft precludes its recovery for repair or refurbishment. A potentially cost effective approach is to provide a Shuttle/Tug compatible system to dock, refurbish/resupply, and redeploy spacecraft. Further advanced technology is desired to support trade studies.

(b) EOS*-A, B, C and D; SMM; EGRET; SSOS; SEOS; SeaSAT** will benefit.

(c) In orbit repair and refurbishment of spacecraft will replace the present method of operations, i.e., launching a second or backup spacecraft to complete the mission of a malfunctioning spacecraft.

Retention devices are required to support the spacecraft during launch of a spacecraft or the return of a spacecraft to earth from orbit.

(d) The test of a model utilizing a spacecraft to demonstrate its applicability will satisfy this technology requirement.

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*EO-08A

**OP-07-A & -09A

TO BE CARRIED TO LEVEL 7

1. TECHNOLOGY REQUIREMENT(TITLE): Spacecraft Docking/Deployment (Latching) and Retention Mechanisms

7. TECHNOLOGY OPTIONS:

(a) Continue present mode of operation of replacement of spacecraft, utilizing non-Shuttle launch vehicles.

(b) Launch spacecraft by the shuttle.

(c) Development of an EVA method for docking and deployment.

(d) Capture and return spacecraft to earth for refurbishment and/or repair.

(e) Capture and return spacecraft to earth for technical analysis.

8. TECHNICAL PROBLEMS:

(a) Minimum weight/maximum reliability design.

(b) Accommodate misalignment of the spacecraft/shuttle mechanism interfaces at the moment of initial engagement.

(c) Effect of thermal gradients on alignment of spacecraft/shuttle mechanism interfaces.

9. POTENTIAL ALTERNATIVES:

There are no known potential alternatives other than those discussed in Section 7.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

(a) EGRET spacecraft, F. J. Cepollina, (301) 982-5913.

(b) RTOP W 74-70824 (970-63-10), Teleoperator Control and Manipulation, W. G. Thornton, MSFC, Huntsville, Ala. (Ph. 205-453-5530)

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

Development of composite material structure to save weight and thermal gradient problems.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-9.8

1. TECHNOLOGY REQUIREMENT (TITLE): Spacecraft Docking/Deployment (Latching) and Retention Mechanisms

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Design Eng. Unit																			
2. Fabricate E/U																			
3. Qualify E/U																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE				△														
NUMBER OF LAUNCHES					2	2	1	2	1	*	1	*	*	1	*	*	*	9

14. REFERENCES:

a. Flight support system for Earth Observation Satellites (NAS5-23203, Mod 4) SD74-SA-0057

b. Letter: NASA/GSFC File No. 8213, Code 730, Subject: "Study of Future Payload Technology Requirements, Contract NAS 2-8272", F. J. Cepollina to H. M. Ikerd, GD Convair, dated 10 January 1975.

c. In-Orbit Servicing by Frank J. Cepollina and James Mansfield, pages 46-56 Astronautics & Aeronautics, Vol. 13, No. 2, dated February 1975.

d. MCR-73-337, NAS 8-29904, Final Report, Shuttle Remote Manned Systems Requirements Analysis prepared for MSFC, by Martin Marietta Corp., February 1974.

Legend: * = Resupply missions
E/U = Engineering Units

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-9.9

1. TECHNOLOGY REQUIREMENT (TITLE): EVA Equipment and Tools for Operations, Repair and Servicing of Spacecraft PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Spacecraft/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: Operate, service, and repair spacecraft in orbit.

4. CURRENT STATE OF ART: Some tools have been utilized in Apollo and Skylab missions; however, advanced power tools are needed.

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

Malfunctioning or depleted spacecraft subsystems, instruments, and appendages can be replaced, remotely, aboard the shuttle in earth orbit. EVA services for planned assembly and test operations in space can also be performed.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) The present method for orbiting a spacecraft precludes its recovery for repair or refurbishment. The cost effective solution is to provide a shuttle compatible system to recover, repair, and reorbit spacecraft.

(b) EOS*-A, B, C and D; SMM; EGRET; SSOS; SeaSAT** will benefit.

(c) In orbit repair and refurbishment of spacecraft will replace the present method of operations, i.e., launching a second or backup spacecraft to complete the mission of a malfunctioning spacecraft.

Planned or contingency EVA will be available, as required, to accomplish operations/resupply/refurbishment mission in the event of failure. This capability can best be utilized if tools, drives, etc., are available to manually correct/override incurred difficulties.

(d) The test of a model utilizing a spacecraft to demonstrate its applicability will satisfy the requirements of this technology item.

*EO-08A

**OP-07-A & -09A

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. C-9.9

1. TECHNOLOGY REQUIREMENT(TITLE): EVA Equipment Tools for Operations, Repair and Servicing of Spacecraft

7. TECHNOLOGY OPTIONS:

(a) Continue the present mode of operation of replacing spacecraft.
(b) Capture and return spacecraft to earth for refurbishment and/or repair.
(c) Development of a remotely controlled automated system for refurbishment of a malfunctioning spacecraft while in earth orbit.

8. TECHNICAL PROBLEMS:

(a) Establish the payload system failure modes and determine which (including drives/tooling) are EVA correctable.

9. POTENTIAL ALTERNATIVES:

There are no known potential alternatives other than those discussed in Section 7.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

(a) Skylab Experience Bulletins 5 and 13, In Flight Maintenance, a Viable Program Element, Robert Gunderson, JSC, September 1974.
(b) Tools, Test Equipment and Consumables to Support In Flight Maintenance, Robert Gunderson, November 1974

(continued on page 4)

EXPECTED UNPERTURBED LEVEL 3

11. RELATED TECHNOLOGY REQUIREMENTS:

Use composite materials for tools to solve weight and dimensional problems.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-9.9

1. TECHNOLOGY REQUIREMENT (TITLE): EVA Equipment and Tools for Operation, Repair and Servicing of Spacecraft — PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Design Eng. Unit																			
2. Fabricate E/U																			
3. Qualify E/U																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				△														
NUMBER OF LAUNCHES					2	2	1	2	1	*	1	*	*	1	*	*	*	9

14. REFERENCES:

a. Flight support and system for Earth Observation Satellites (NAS5-23203, Mod 4) SD74-SA-005

b. Letter: NASA/GSFC File No. 8213, Code 730, Subject: "Study of Future Payload Technology Requirements, Contract NAS 2-8272", F. J. Cepollina to H. M. Ikerd, GD Convair, dated 10 January 1975.

c. In-Orbit Servicing by Frank J. Cepollina and James Mansfield, pages 46-56 Astronautics & Aeronautics, Vol. 13, No. 2, dated February 1975.

d. Tools, Test Equipment and Consumables to Support In-Flight Maintenance, Robert Gunderson, Nov. 1974.

Legend: * = Resupply missions
E/U = Engineering Unit

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-9.9

1. TECHNOLOGY REQUIREMENT (TITLE): EVA Equipment Tools for Operations, Repair and Servicing of Spacecraft PAGE 4 OF 4

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:
(Continued from page 2)

(c) Contributing contracts -

(1) In Flight Maintenance Study
Martin NAS 9-8144

(2) Application of EVA Guidelines and Design Criteria
Matrix NAS 9-12997

(3) Maintenance of Manned Spacecraft for Long Duration Missions
Boeing NAS 2-3705

(4) Space Shuttle Support Equipment Requirements Study EVA/IVA
Hamilton Standard NAS 9-12506

(5) Study of Space Shuttle EVA/IVA Support Requirements
LTV NAS 9-12507

(6) Role of RMS in EVA for Shuttle Mission Support
Essex NAS 9-13717

(7) Study to Evaluate Effects of EVA on Payload Systems
Rockwell NAS 2-8249

(8) Space Shuttle Orbiter Logistics Support Plan
Rockwell SD-T3-SH-0188A

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-9.10

1. TECHNOLOGY REQUIREMENT (TITLE): Remote Manipulator System (RMS) End Effector Mechanism - Shuttle to Spacecraft PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Spacecraft/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: To release or retrieve a Spacecraft or to Resupply/Refurbish a Spacecraft while in earth orbit

4. CURRENT STATE OF ART: Preliminary design concept

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

(a) Spacecraft will be removed from the shuttle orbiter cargo bay and placed into earth orbit by the RMS.

(b) Spacecraft will be retrieved from earth orbit and placed into the shuttle orbiter cargo bay for resupply/refurbishment or return to earth using the RMS.

(c) Malfunctioning or depleted spacecraft appendages such as a solar array may be replaced while in earth orbit using the RMS.

(d) Special end effectors other than the basic orbiter end effector will be designed and provided by the payload requiring the special end effector. However, a set of techniques for non-standard end effectors will help reduce costs.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) The present method for orbiting a spacecraft precludes its recovery for repair or refurbishment. The cost effective approach is to provide a shuttle compatible system to dock, refurbish/resupply, and redeploy spacecraft.

(b) EOS*A, B, C and D; SMM; EGRET; SSOS; SEOS; SeaSAT** will benefit.

(c) In orbit repair and refurbishment of spacecraft will replace the present method of operations, i.e., launching a second or backup spacecraft to complete the mission of the malfunctioning spacecraft.

A mechanism is required to interface between the orbiter RMS and the spacecraft to effect both the launch and retrieval of free flying spacecraft with a reasonable degree of safety.

The mechanism is required also to replace spacecraft appendages using the RMS.

(d) The test of a model of the mechanism in conjunction with a spacecraft to demonstrate its applicability will satisfy this technology requirement.

*EO-08A

**OP-07-A & -09A

TO BE CARRIED TO LEVEL 7

*Technology by GDFC, F. J. Cepollina and associates.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. C-9.10

1. TECHNOLOGY REQUIREMENT(TITLE): Remote Manipulator System (RMS) End Effector Mechanism - Shuttle to Spacecraft — PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

(a) Continue present mode of operations, reference 6c, utilizing non-shuttle launch vehicles.
(b) Launch spacecraft by the shuttle.
(c) Development of an EVA and/or Shuttle attached manipulator system.
(d) Capture and return of spacecraft to earth for refurbishment and/or repair.
(e) Capture and return of spacecraft to earth for technical analysis.
(f) Use of astronaut EVA with special tools and devices to accomplish manipulator end effector tasks.

8. TECHNICAL PROBLEMS:

(a) Minimum weight/maximum reliability with a reasonable degree of safety.
(b) Engagement possible over a reasonable range of spacecraft RMS misalignment.
(c) Effect of thermal gradients on the engagement of the RMS end effector/spacecraft interfaces.

9. POTENTIAL ALTERNATIVES:

There are no known potential alternatives other than those discussed in Section 7.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

(a) RTOP 74-70824 (970-63-20), Teleoperator Control and Manipulation, W. G. Thornton, (Ph. 205-453-5330)
(b) W 74-70817 (970-53-20) Attached Manipulator System, Richard B. Davidson (Ph. 713-483-4986)

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

Use of composite materials to solve weight and dimensional problems.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-9.10

1. TECHNOLOGY REQUIREMENT (TITLE): Remote Manipulator System (RMS) End Effector Mechanism - Shuttle to Spacecraft PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Design Eng. Unit	—																		
2. Fabricate E/U	—	—																	
3. Qualify E/U		—																	
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)			—																
2. Devl/Fab (Ph. D)				—															
3. Operations					—	—	—	—	—	—	—	—	—	—	—	—	—		
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				△														
NUMBER OF LAUNCHES					2	2	1	2	1	*	1	*	*	1	*	*	*	9

14. REFERENCES: (a) EVA/RMS Payload Requirements Work Shop, Oct. 2, 1974, MSFC NASA-S-74-11505, RMS Design, R. Davidson, JSC.

(b) Flight Support and System for Earth Observation Satellites (NAS5-23203, Mod 4) SD 74-SA-0057

(c) Letter: NASA/GSFC File No. 8213, Code 730, Subject: "Study of Future Payload Technology Requirements, Contract NAS 2-8272", F. J. Cepollina to H. M. Ikerd, GD Convair, dated 10 January 1975.

(d) In-Orbit Servicing by Frank J. Cepollina and James Mansfield, pages 46-56 Astronautics & Aeronautics, Vol. 13, No. 2, dated February 1975.

(e) MCR-73-337, NAS 8-29904, Shuttle Remote Manned System Requirements Analysis, Final Report, Martin/Marietta for MSFC, Feb. 1974.

Legend: * = Resupply Missions
E/U = Engineering Units

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-9.11

1. TECHNOLOGY REQUIREMENT (TITLE): Spacecraft to Tug Docking Mechanism PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Spacecraft/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: To resupply and refurbish three-axis stabilized and spin stabilized geo-synch satellites.

4. CURRENT STATE OF ART: Preliminary engineering studies have been initiated to investigate feasibility of docking mechanism.

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

Malfunctioning or depleted spacecraft systems could be replaced remotely by Shuttle or earth controlled tug, at synchronous altitude therefore the spacecraft would not have to be abandoned or returned to earth for rework and/or refurbishment. However, remotely controlled docking mechanisms are needed to hold the satellite during servicing. Docking mechanisms are also necessary for retrieval of payloads by the tug.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) The present method for positioning a spacecraft at synchronous altitude precludes its recovery for repair and/or refurbishment. A potentially cost effective solution is to provide a shuttle/tug mechanism to remotely service synchronous orbit spacecraft. Further technology development may be necessary to reduce costs and support trade studies.

(b) All compatible spacecraft at synchronous altitude will benefit from this technology advance; e.g., Earth and Ocean Physics, Communication/Navigation, and Earth Observations payloads.

(c) In orbit repair and/or refurbishment of spacecraft would replace the present method of operation, i.e., launching a second or back-up spacecraft to continue the mission of the malfunctioning spacecraft.

(d) The test of a model of a docking mechanism utilizing a spacecraft to demonstrate its applicability will satisfy this technology requirement.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. C-9.11

1 TECHNOLOGY REQUIREMENT(TITLE): Spacecraft to Tug Docking Mechanism — PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

(a) Capture and return of spacecraft to orbiter for repair and/or refurbishment.

(b) Capture and return of spacecraft to earth via orbiter for repair and/or refurbishment.

(c) Continue present mode of operation of total replacement of satellites.

(d) Technology options for the docking mechanisms are: impact and non-impact methods. Lower level options are probe and drogue, latching frame, and other geometrical configurations.

8. TECHNICAL PROBLEMS:

(a) Development of TV controlled position sensing and alignment system.

(b) Effect of thermal gradients across tug mechanism/spacecraft interface.

9. POTENTIAL ALTERNATIVES:

There are no known potential alternatives other than those discussed in Section 7.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. MSFC: Space Tug Docking Study, 1975 RFP.

b. SAMSO/Bell Aerospace, Tug Rendezvous and Docking Studies.

EXPECTED UNPERTURBED LEVEL 3

11. RELATED TECHNOLOGY REQUIREMENTS:

Development of encoder system to assist remote control determination of location of malfunctioning system and checkout of replacement system.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C-9.11

1. TECHNOLOGY REQUIREMENT (TITLE): Spacecraft to Tug Docking Mechanism

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Design Phase																			
2. Fabrication E/U																			
3. Testing & Qual.E/U																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE							△											
NUMBER OF LAUNCHES									*	*	*	*	*	*	*	*	*	

14. REFERENCES:

(a) NASA Management Instruction 8020.22 dated 1 October 1974.

(b) Letter: NASA/GSFC File No. 8213, Code 730, Subject: "Study of Future Payload Technology Requirements, Contract NAS 2-8272", F. J. Cepollina to H. M. Ikerd, GD Convair, dated 10 January 1975.

(c) In-Orbit Servicing by Frank J. Cepollina and James Mansfield, pages 46-56 Astronautics & Aeronautics, Vol. 13, No. 2, dated February 1975.

(d) MCR-73-337 (NAS 8-29904) Shuttle Remote Manned Systems Requirements Analysis, Final Report - Martin/Marietta for MSFC, February 1974.

Legend: * = Resupply Missions
E/U=Engineering Unit

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RI,10.1

1. TECHNOLOGY REQUIREMENT (TITLE): MULTIPLE INSTRUMENT CHAMBER

2. TECHNOLOGY CATEGORY: Environmental Control

3. OBJECTIVE/ADVANCEMENT REQUIRED: Construct a mechanism operable in a cryogenic environment which will enable focusing of focal plane energy on detectors of between 2 and 6 IR instruments.

4. CURRENT STATE OF ART: USAF has developed and operated a Michelson interferometer with moving parts in a cryogenic environment.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

The Multiple Instrument Chamber (MIC) will contain 2 to 6 IR band instruments to be developed by investigators, and 2 visible band instruments (an imaging CCD array, and a focal plane tracker). The visible band instruments provide pointing correction to the stabilization and tracking loop and also permits visible band observation of areas in the IR instruments FOV. The IR band instruments will investigate faint sources of IR energy. The mechanism for energy transfer remains to be designed. Current considerations include use of a dichroic element to reflect IR band energy and pass visible band energy to their respective detectors from a reflecting telescope surface. The IR detectors are maintained at various cryogenic temperatures which causes the primary problem considered herein which is operation of a precision mechanism without contamination of cold surfaces.

(continued on page 2)

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. The MIC is a part of the Shuttle Infrared Telescope Facility (SIRTF) and permits selection of 2 to 6 IR instruments of IR astronomy investigations.

b. (benefiting payloads)
   - AS-01-S - 1.5 m cryogenically cooled IR telescope - ØA
   - AS-14-S - 1 m uncooled IR telescope - pre ØA
   - AS-15-S - 3 m ambient temperature IR telescope - pre ØA
   - AS-20-S - 2.5 m cryogenically cooled IR telescope - pre ØA
   - AS-07-A - 3 m ambient temperature IR telescope - pre ØA

c. The ability to use the MIC to select an instrument enables multiple observation of phenomena using different spatial and spectral sensitivities and resolutions. Cooling the detectors and instruments results in optimization of S/N ratio for observation of faint IR sources against faint backgrounds.

d. The technology is now available in the form of potential components to initiate design of the MIC. The unit must be developed with final technology demonstration test in space.

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TO BE CARRIED TO LEVEL 7

Multiple Instrument Chamber

Description of Technology (continued)

Cooling requirements are tentatively listed as:

Overall telescope - expansion of supercritical He gas enabling temperatures of 10-20°K.

Gas is expanded by Joule-Thompson loop hopefully to bring temperature down to 1°K for some detectors

Other detectors will require temperatures of 4-10°K, with some at 20°K

The MIC concept is presently being developed by the Hughes Company, Culver City. Cooling requirements will be defined by August 1975 with additional requirements to be defined by experimenters after that date.

The possibility of technology transfer of cryogenic developments applicable to RI 12.2 should be investigated.

The envelope of the MIC is illustrated in Figure 1.

MULTIPLE INSTRUMENT CHAMBER ENVELOPE

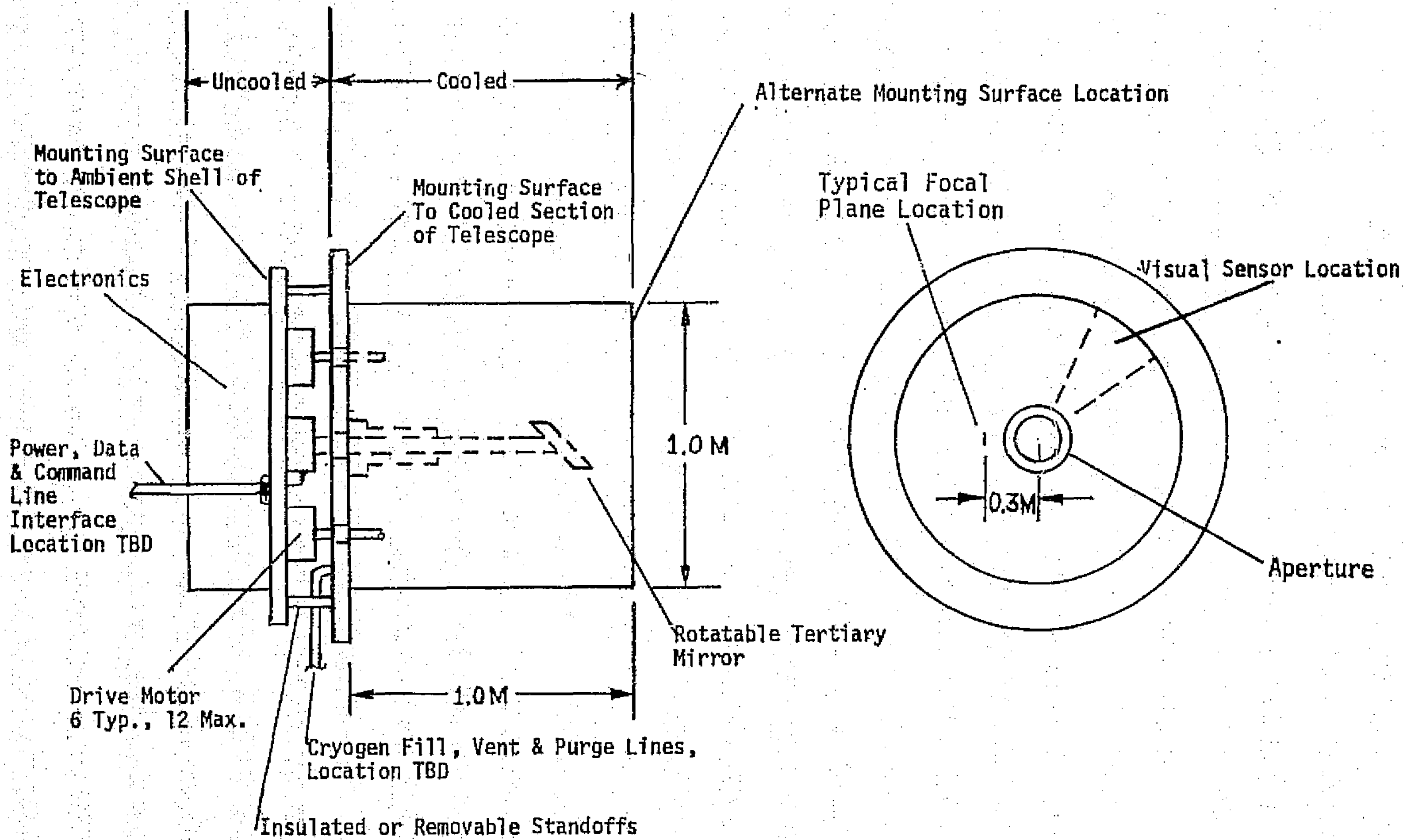

Figure 1 (see Reference 1)

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RI, 10.1

1. TECHNOLOGY REQUIREMENT(TITLE): ______ PAGE 4 OF 6
Multiple Instrument Chamber

7. TECHNOLOGY OPTIONS:

The MIC cryogenic system remains to be defined as either a dewar system or a refrigeration machine. It appears likely that the dewar is a valid consideration for the sortie missions. However, the automated mission AS-07-A has a three-year life and probably could fully utilize a cooler with Joule-Thompson expansion loop.

8. TECHNICAL PROBLEMS:

a. Development of a zero gravity cryogenic He container

b. Contamination prevention on cold surfaces in a differential temperature area

c. Development of rotary cryogen joints without leakage or significant friction

d. Addition of Joule-Thompson expansion techniques to current refrigeration machines under development (see RI 12.2) to lower temperature from 20°K to 1°K.

9. POTENTIAL ALTERNATIVES:

Individual instruments are not a viable alternative because the value of the MIC is its ability to save weight because its instruments share the same telescope.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. Zero-G cryogenic containers - Dr. Urban, MSFC

b. IR detector development - Hughes

c. Contamination prevention - Dr. Ress, Martin Marietta ; Hughes, Culver City

(continued on page 5)

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

a. IR detector, CCD, and pre amp development operable from 30 to 200 μ

b. Development of long IR wavelength filters with narrow bandwidths and sharp cutoffs.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RI,10.1

1. TECHNOLOGY REQUIREMENT (TITLE): Multiple Instrument Chamber PAGE 5 OF 6

Planned Programs or Unperturbed Technology Advancement (continued)

d. Long wavelength filter development - current British development

e. Honeywell Radiation Center in connection with USAF CRL has developed a Michelson interferometer.

DEFINITION OF TECHNOLOGY REQUIREMENT

NO. RI-10.1

11. TECHNOLOGY REQUIREMENT (TITLE): ______________________ PAGE 6 OF 6

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. MIC Requirements Defined																			
2. Breadboards/Tests																			
3. Life Testing																			
4. Engineering Model/ Testing																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4. Shuttle Sortie Operations (all others)																			

NOTE: To meet Technology Need Date MIC requirements must be hardened. Present schedule is experimenters will define cooling requirements in 1976. The dewar and machine technology will be available ~ 1/77.

13. USAGE SCHEDULE:

TECHNOLOGY NEED DATE			▼															TOTAL
NUMBER OF LAUNCHES						3	3	3	6	4	2	1	2	3	3	3	3	36

14. REFERENCES:

1. Performance Requirements for Space Shuttle Infrared Telescope Facility (SIRTF) Specification 2-24483, NASA-Ames, July 15, 1974.
2. Technical discussion between J. Kirkpatrick, NASA-Ames, and P. R. Fagan, Rockwell International, 2 November 1974.
3. Technical discussion between F. Witteborn, NASA-Ames, and P. R. Fagan, Rockwell International, 3 November 1974
4. Letter from C. McCreight, NASA-Ames to H. Ikerd, GDCA, December 31, 1974.
5. Discussion between C. McCreight, NASA-Ames, and P. R. Fagan, Rockwell International, October 8, 1974.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. RI, 10.4

1. TECHNOLOGY REQUIREMENT (TITLE): ZERO-GRAVITY STEAM GENERATOR — PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Environmental Control

3. OBJECTIVE/ADVANCEMENT REQUIRED: Obtain data on steam generator performance under zero-g conditions.

4. CURRENT STATE OF ART: Engineering model in operation at Langley Research Center and undergoing testing.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

The object of this experiment is to obtain steam generator performance data during operation in near-zero gravity in earth orbit. The dynamics of steam at zero gravity is of interest because a promising technique for removing CO_2 from cabin air is steam desorption which utilizes steam to displace absorbed CO_2 from the sorbent beds in the system. LaRC Systems Engineering Division personnel are developing a steam generator for this steam desorption system. The phase-change and heat-transfer processes involved in the steam generator are expected to be gravity sensitive. At reduced gravity levels, performance parameters such as amount of steam generated and steam quality are difficult to predict analytically or to simulate with ground tests. The steam generator performance data obtained in this experiment will be of value in verifying analytical performance prediction methods as well as for design applications.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Requirements defined by need for efficient method for scrubbing spacecraft cabin air.

b. ST-22-S, ATL Payload No. 3 (Module + Pallet)

c. Scrubbing sorbent beds extend the life of environmental life support systems.

d. Zero gravity cannot be simulated to extent to assure testing in a relevant environment. As a minimum, a test in a zero-g high altitude rocket such as an Aries launch would meet the initial technology requirement.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RI, 10.4

1. TECHNOLOGY REQUIREMENT(TITLE): ZERO-GRAVITY STEAM GENERATOR PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

None defined.

8. TECHNICAL PROBLEMS:

Compaction of heat transfer surfaces

9. POTENTIAL ALTERNATIVES:

Sodium peroxide (NO_2O_2) and potassium superoxide (KO_2) can serve to absorb water and carbon dioxide and regenerate oxygen.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Engineering model presently being tested. Flight article construction is the next step anticipated.

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

None defined.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. RI, 10.4

1. TECHNOLOGY REQUIREMENT (TITLE): ZERO-GRAVITY STEAM GENERATOR — PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY			COMPLETE																
1. TESTING OF ENGINEERING MODEL																			
2. FABRICATE FLT MODEL																			
3. TEST FLIGHT MODEL																			
4.																			
5.																			
APPLICATION					CONTRACT AWARD (PRESENT SCHEDULE)														
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE				▼														
NUMBER OF LAUNCHES							1		1	1		1	1					5

Scheduled acquisition of final article is well ahead of technology need date.

▼ Technology need date.

14. REFERENCES

a. Study of Shuttle-Compatible Advanced Technology Laboratory (ATL), Langley Research Center, NASA TMX-2813, September 1973.

b. Technical discussions between C. Tynan and D. Barthlome, Langley Research Center; and P. R. Fagan, Rockwell International, Nov. 7, 1974.

c. Letter from D. Barthlome, Langley Research Center to P. R. Fagan, Rockwell International, November 12, 1974

d. Letter from D. Barthlome, Langley Research Center to H. Ikerd, GDCA, December 30, 1974

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. RL.11.1

1. TECHNOLOGY REQUIREMENT (TITLE): Structure/Mechanism — PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Environmental Protection

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development of method for operating electronic components and circuits at 750 K and 100 atmospheres.

4. CURRENT STATE OF ART: Some silicon carbide devices have operated reliably above 750 K

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Complex circuitry is generally restricted to temperatures near 400 K; however, individual silicon devices which have been carefully selected and derated have been operated to 500 K. Various types of SiC rectifiers, thermistors, sensors, and prototype field effect transistors have operated with long lifetime above 750 K. There is no possibility of increasing the capability of silicon devices to 750 K.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. The payload will operate from the Venus surface. Best estimates of conditions are 750 K and 100 atm.
b. PL-10-A Venus Large Lander
c. The lander will be required to maintain a communications link during the period of Venus surface data collection. The extreme environment of the surface can possibly damage the electronics.
d. Demonstration of the capability of electronics to operate reliably in a simulated Venus environment.

TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. RI, 11.1

1. TECHNOLOGY REQUIREMENT(TITLE): Structure/Mechanism — PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

a. Design of encapsulated environmentally protected system.
b. Development of SiC devices which are capable of 750 K operation.
c. Development of wide band gap semi conductors such as SiC or GaP.
d. Some thermal lagging and heat sinks.

8. TECHNICAL PROBLEMS:

Thermal lagging and heat sinking will restrict operation to short periods of time and would cause a severe weight penalty.

9. POTENTIAL ALTERNATIVES:

Unknown

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. USAFCRL investigating SiC devices

b. USAF Rome Air Development Center is publishing MIL Handbook 217B on high temperature acceleration.

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

Entry probe, Pioneer Series, see Item C-9.5.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 11.1
1. TECHNOLOGY REQUIREMENT (TITLE): ____________	PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis/Designs																			
2. Breadboards																			
3. Testing																			
4. Life Testing																			
5. Engineering Model																			
6. Testing																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Integration into Spacecraft & Testing																			
4.																			

NOTE: SiC & GaP electronics will probably be used with encapsulated detectors for protection. Present NASA philosophy is for encapsulation.

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES															2			2

14. REFERENCES:

1. Discussion between H. Hendricks, Langley Research Center, and P. R. Fagan, Rockwell International, November 18, 1974.
2. Letter from R. B. Campbell, Westinghouse Electric Corp., to H. Ikerd, GDCA, December 10, 1974.
3. Discussion between J. Plemondon, Jet Propulsion Laboratory, and P. R. Fagan, Rockwell International, January 20, 1975.
4. Discussion between W. Marco, Jet Propulsion Laboratory, and P. R. Fagan, Rockwell International, February 3, 1975.
5. Preliminary Study of the Feasibility of a Venus Lander, Memorandum from Westinghouse Electric Corp. to NASA-GSFC, May 3, 1970.
6. Feasibility of Hot Pressed Silicon Carbide as a Substrate for High Power Laser Mirrors, Technical Memo, Westinghouse Astronuclear Laboratory, February 6, 1974.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. RI, 12.1

1. TECHNOLOGY REQUIREMENT (TITLE): He Cryostat Dewar — PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Cryogenic Control

3. OBJECTIVE/ADVANCEMENT REQUIRED: 1.6°K for one year

4. CURRENT STATE OF ART: Cryostat models have been constructed at MSFC.

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY – Phase Change Systems

	(MSFC Definition for LHe Dewar)	(HEAO-B Cosmic Ray Spectrometer Cryostat Model Under Development)
Weight	100-200 lb	3300 lb*
Life	1 year	1 year
Temperature	1.5°K	4-5°K
Load	30 milliwatts	unknown
Dimensions	See Figure 1	72 in. dia. x 95 in. length

*Not state-of-art and will be reduced

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Summary and Rationale
The cryostat dewar will be used to provide LHe at 1.6°K to both the relativity gyroscope and telescope star tracker for a period of one year to confirm or deny various relativity theories. 1.6°K LHe is required for the gyroscope experiment to eliminate cavitation type noise from higher temperature evaporation (HE II does not form bubbles during evaporation) and to ensure that the structural changes with temperature are minimized. LHe will be also used to cool the detectors of the telescope star tracker to lower internal noise and increase the S/N ratio.

b. Benefitting Payloads
AP-04-A Gravity and Relativity Satellite – LEO (Phy-2) and ST-31S "Drop Dynamics Facility"

c. Justification
Advancement will contribute to sensing of precession to 10^{-3} arc-sec/year relative to the background star field.

d. A number of dewars have been tested. Ball Brothers has tested a dewar of approximate size and life required. A mechanical model has been given a Thor-Delta shake test to determine if dewar concept can withstand rigors of a high vibration launch. A thermal model will be tested at Ball Brothers within six months to define performance. Technology has been essentially defined and no future state-of-the-art problems are anticipated.

The cryostat dewar used for the Gravity and Relativity Satellite will be acceptable based upon demonstrated capability of a lesser operational model, possibly on an Explorer mission in conjunction with relativity gyroscope tests.

TO BE CARRIED TO LEVEL 8

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DEFINITION OF TECHNOLOGY REQUIREMENT — NO. RI, 12.1

1. TECHNOLOGY REQUIREMENT(TITLE): He Cryostat Dewar — PAGE 2 OF 4

7. TECHNOLOGY OPTIONS:

LHe temperatures above 2.17°K will result in vibrational noise on the gyroscope reducing its ability to measure relativity effects. Disturbances caused by mechanical refrigerators and closed cycle operation would be intolerable. A temperature higher than 4°K will cause excessive loss of helium as well as impacting the performance of superconducting instruments and components. Switching to another cryogen will cause greater losses.

8. TECHNICAL PROBLEMS:

a. Design of a low heat leak neck view port. No suitable ports exist at the present time.
b. Venting with superfluid has not been demonstrated in space.
c. Full scaled tests must be conducted to assure no problems.
d. Development of prelaunch fill and dewar servicing techniques.

9. POTENTIAL ALTERNATIVES:

1.6°K must be maintained for at least one year. On orbit resupply may be feasible but is most undesirable. Closed cycle systems will require very high power and introduce vibration, etc.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. System study of closed cycle rotary reciprocating 3.6°K refrigerator conducted and some compoents built (see Reference 2)

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

No related technology requirements for phase change system as it is state of the art. However, if closed cycle system is used, power becomes a major consideration necessitating large, very efficient solar arrays.

1. TECHNOLOGY REQUIREMENT (TITLE): He Cryostat Dewar

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Options & Parametric Analysis	—																		
2. Design	—	—																	
3. Construct Models		—																	
4. Test Models		—	—																
5. Engineering Model/ Test			—																
APPLICATION																			
1. Design (Ph. C)				—															
2. Devl/Fab (Ph. D)					—														
3 Operations																			
4.																			

NOTE: Continued funding required to meet technology need date. Schedule appears very tight.

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				▼														
NUMBER OF LAUNCHES						1			1									2

14. REFERENCES:

1. P. E. Wright, Refrigeration Systems for Spacecraft, RCA Advanced Technology, Publication of RCA Advanced Technology Laboratories, Camden, New Jersey, 1972
2. Breckenridge, R. W. and Gabron, F., Cryogenic Cooling for Spaceborne Experiments, Engineering Division, Arthur D. Little, Inc., Proceedings Cryogenic Workshop, MSFC, March 29-30, 1972
3. Lipa, J. A., et al, Research at Stanford on the Containment of Liquid Helium in S pace by a Porous Plug and a Long Hold-Time Dewar for the Gyro Relativity Experiment, W. W. Hansen Laboratories of Physics, Stanford University, Proceedings of Cryogenic Workshop, MSFC, March 29-30, 1972
4. Technical discussions at MSFC between Dr. E. Urban, MSFC, and P. R. Fagan, Rockwell International, October 17, 1974
5. Letter from J. Lipa, Hansen Laboratories, Stanford U., to H. Ikerd, GDCA, Dec. 17, 1974.
6. Letter from C. McCreight, NASA Ames to H. Ikerd, GDCA, December 31, 1974.
7. Letter from R. S. Hunt, Garrett-Airresearch Manufacturing Co., to H. Ikerd, GDCA, January 6, 1975
8. Letter from Dr. E. Urban, MSFC to H. Ikerd, GDCA, January 7, 1975

15. LEVEL OF STATE OF ART

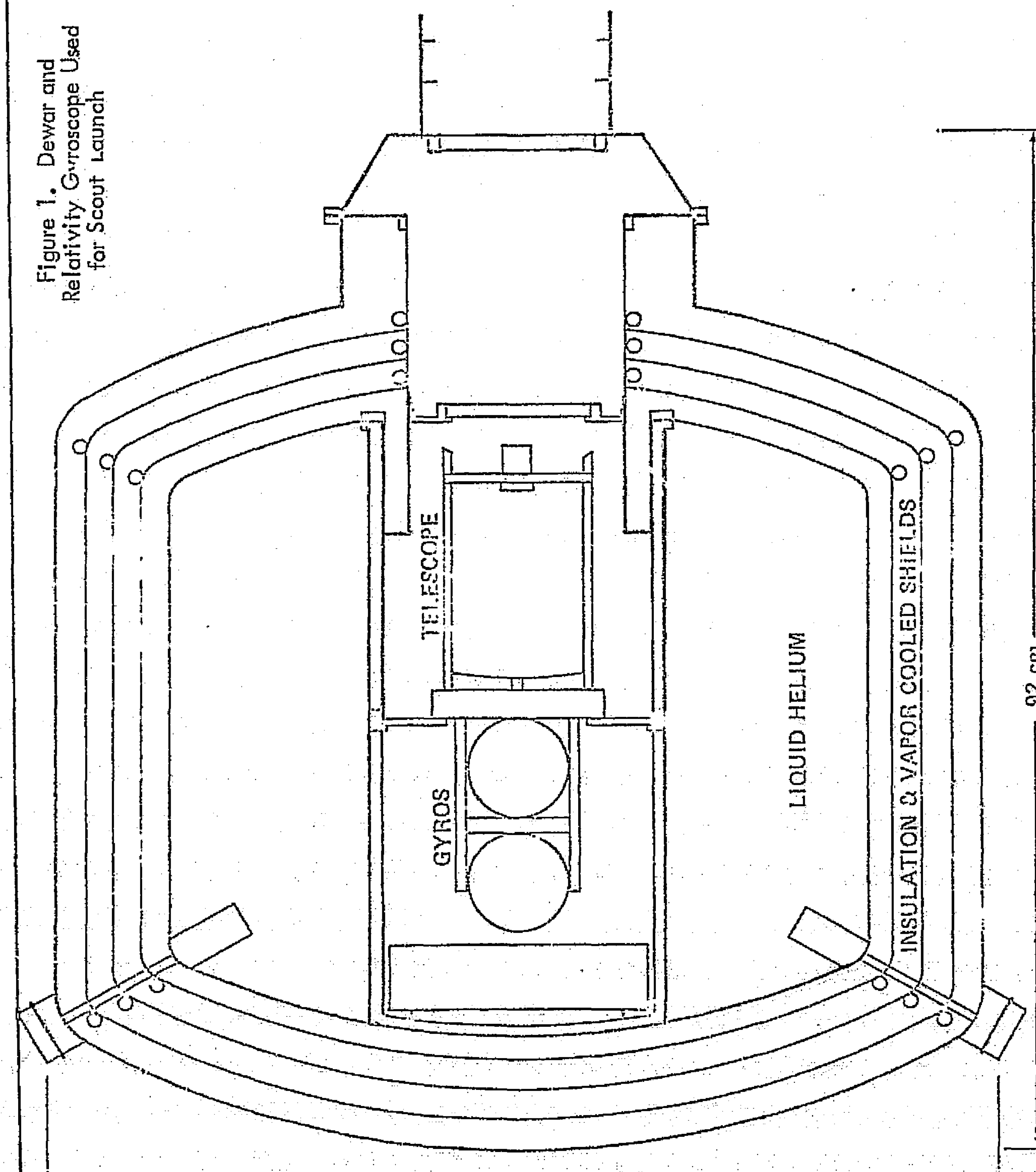
1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT

NO. RI, 12.1

1. TECHNOLOGY REQUIREMENT (TITLE): He Cryostat Dewar

Figure 1. Dewar and Relativity Gyroscope Used for Scout Launch



DEFINITION OF TECHNOLOGY REQUIREMENT NO. RI-12.2

1. TECHNOLOGY REQUIREMENT (TITLE): LHe Recycling Unit PAGE 1 OF 6

2. TECHNOLOGY CATEGORY: Cryogenic Control

3. OBJECTIVE/ADVANCEMENT REQUIRED: Provide LHe refrigeration machines to cool payload items noted below.

4. CURRENT STATE OF ART: Elements of machine under construction and test. Engineering model will be available for testing by 1-1976.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

The DoD has been funding development of low temperature refrigerators. An early investigation was a three-year program to develop a long life 3.6 K, one watt load refrigerator for use with a superconducting computer system. The effort by Arthur D. Little, Inc. was terminated after one year.

Three companies have since been funded for development of closed cycle refrigeration systems; they are:

Hughes Aircraft Corp.
North American Phillips Inc.
Arthur D. Little Inc.

(continued on page 4)

See Table 1 below

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Table 1. Payload Requirements

Payload	Status	Payload	Status	Payload	Status
AS-03-A	Pre Phase A	HE-09-A	Phase B	AS-15-S	Pre Phase A
AS-07-A	Pre Phase A	AS-01-S	Pre Phase A	AS-20-S	Pre Phase A
AS-11-A	Pre Phase A	AS-14-S	Pre Phase A	HE-15-S	Phase B

a. Temperature requirements result from two factors:
   1. Requirements for superconduction which defines operational temperature of magnets and permits low power measurement of particle energies.
   2. Requirements for high detectability and high S/N ratio which requires detector cooling and allows detection of faint IR sources.

b. See Table 2

c. The use of LHe closed cycle systems permit long life missions without resupply or large dewar requirements

d. Space flight testing of a prototype model

TO BE CARRIED TO LEVEL 7

1. TECHNOLOGY REQUIREMENT(TITLE): LHe Recycling Unit

7. TECHNOLOGY OPTIONS:

Two Brayton cycles and various others should be investigated; they are:

1. Reciprocating Reverse Brayton Cycle
2. Rotary Reverse Brayton Cycle
3. Rotary Claude Cycle
4. Dual Phased Recuperated Vuilleumeir Process
5. Hybrid Systems – which combine mechanical refrigeration with other techniques such as dielectric cooling

8. TECHNICAL PROBLEMS:

a. In discussion with Arthur D. Little, Inc., it was determined that primary technical problems are in the area of fabrication of system items and no major problems are forseen. It can be seen from the scheduled availability of the ADL unit for life testing as of January 1976, that the unit modified to the necessary cooling requirements will not be available by the technology need date. The early payloads may be more suited to using the dewars currently under development until the technology is developed by WPAFB for cooling machines.

b. Maintenance of close tolerances during operation

9. POTENTIAL ALTERNATIVES:

It can be seen from Table 2 that a number of the payloads which are listed as desirable to incorporate closed cycle systems are Shuttle sortie payloads of seven-day duration. The weights of the refrigerators are estimated as:

North American Phillips VM – 130 pounds
Hughes VM – 180 pounds
ADL Rotary Reciprocating – 300 pounds prior to modification for lower temperatures

(continued on page 5)

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

The ADL unit will be at the stage for initiating life testing about January 1976; however, the minimum temperature it will be capable of operating to will be 11.5 K at 0.3 watts. No modification to lower temperature capabilities required for these payloads is planned.

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

Use of closed cycle systems will require a source of high power. Related technology will be highly efficient large solar arrays, or focusing solar collectors capable of providing thermal power.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RI-12.2

1. TECHNOLOGY REQUIREMENT (TITLE): LHe Recycling Unit PAGE 3 OF 6

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Engineering Model Design																			
2. Life Testing																			
3. Development through development testing																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations AS-03-A																			
AS-07-A																			
4. AS-11-A																			
HE-09-A																			

NOTE: Technology need date seriously impacts required time for development and testing.

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE			▼															
NUMBER OF LAUNCHES					1	4	5	5	8	4	3	2	4	3	5	4	4	52

14. REFERENCES:

1. Conversation between R. W. Breckenridge, Arthur D. Little, Inc., and P. R. Fagan, Rockwell International, Inc., Nov. 27, 1974
2. Conversation between J. Kirkpatrick, NASA-ARC, and P. R. Fagan, Rockwell International, Inc., Nov. 20, 1974
3. Development of Rotary Reciprocating Cryogenic Refrigerator for Space Applications, R. W. Breckenridge, Jr., et al, Arthur D. Little, Inc., AFFDL-TR-72-88
4. Letter from R. S. Hunt, Garrett-Airresearch Co., to H. Ikerd, GDCA, January 6, 1975.
5. Letter from J. Kirkpatrick, NASA-ARC, to H. Ikerd, GDCA, January 6, 1975.
6. Letter from Dr. E. Urban, MSFC, to H. Ikerd, GDCA, January 5, 1975.
7. Letter from C. McCreight, NASA-ARC, to H. Ikerd, GDCA, January 7, 1975.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

1. TECHNOLOGY REQUIREMENT (TITLE):
LHe Recycling Unit

Description of Technology (continued)

The Hughes Vuilleumier (VM) cycle refrigerator is the furthest along in the development cycle and is best suited for near-term missions. However, its performance at low temperatures is relatively poor. Unattended operational life on the order of three years is problematic as the dry lubricated Hughes VM has not been able to demonstrate long life, as yet.

Hughes and North American Phillips are both developing VM cycles and the requirements to which they are working are to simultaneously produce:

0.3 w at 11.5 K
10 w at 33 K
12 w at 75 K

Additional requirements are to draw 2700 watts in the all electric mode and in the thermal-electric mode draw 2600 w or less of thermal power and 500 watts of electric power.

For missions beyond the near term, the Arthur D. Little (ADL) rotary reciprocating refrigerator offers the greatest potential. It is a positive displacement machine, but because of funding lags the VM in development cycle. The prototype is in the fabrication cycle and complete refrigeration testing is expected about January 1976. The ADL device has the advantage of relatively high performance and long life, by virtue of hydrodynamic lubrication achieved by the pistons rotary stroking motion. The ADL device is capable of simultaneously producing

1.4 w at 12 K
40 w at 60 K

It can be seen from Table 2 that the above minimum temperatures of the three noted companies are too high for detectors or superconducting magnets, although they are suitable for providing internal cooling to the IR telescopes.

In discussions with R. W. Breckenridge, Arthur D. Little, Inc., he stated that the rotary reciprocating unit currently under development and noted above is capable of one watt load at 3.6 K at a required input power of 1300 watts. Further extrapolation to 2.5 K will result in a requirement for about 1900 watts for a one watt load. This capability could be achieved through the addition of another Joule-Thompson loop which will require another stage compressor and heat exchanger.

VM cycles cannot be operated at temperatures on the order of those required for detectors listed in Table 2.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RI-12.2

1. TECHNOLOGY REQUIREMENT (TITLE): LHe Recycling Unit PAGE 5 OF 6

5. Description of Technology (continued)

The potential availability of an LHe cryogenic machine can be tempered somewhat by:

1. As yet no complete miniature He refrigerator (or liquifier has demonstrated the capability for providing useful refrigeration at any temperature under 10 K.

2. The longest endurance run that has been conducted to date on a cryogenic refrigerator (Vuilleumier device operating at 80 K) is slightly in excess of 5000 hours. Demonstrating the capability of operating for periods in excess of one year may prove to be a practical impossibility due to outgassing or the accumulation of wear products irrespective of quantities involved.

3. No tests have been done to confirm the possibility that an LHe cryogenic machine can withstand the launch and space vehicle environmental conditions.

9. Potential Alternatives (continued)

Additionally the machine will require a power input on the order of two to three thousand watts. At least for short term Shuttle sortie missions of 7 days it appears feasible to consider open cycle phase change dewars. The advantages are no or little power requirements and probable operation within the weights defined above. A prototype dewar is presently being prepared for thermal testing at Ball Brothers. It was designed for one year operation at 30 milliwatt heat leak and weight of 200 pounds. The dewar will cool the relativity gyroscope to 1.6 K. (See RI, 12.1)

Table 2. Payload Cryogenic Requirements

PAYLOAD	NAME	TEMPERATURE REQUIREMENTS (DETECTORS OR MAGNETS)	LIFE	LOAD (WATTS)
AS-03-A	COSMIC BACKGROUND EXPLORER	3° ± 1.2°K	1 YEAR	<1
AS-07-A	3-M AMBIENT TEMP IR TELESCOPE	1-4°K	1-3 YEARS	<1
AS-11-A	1.5-M IR TELESCOPE	1-4°K; 20 ± 1°K TELESCOPE	3 YEARS	<1
HE-09-A	LARGE HIGH-ENERGY OBSERVATORY B	4°K	1-2 YEARS	0.2
AS-01-S	1-M COOLED IR TELESCOPE	2±0.5°K; 20±1°K TELESCOPE	7 DAYS	<1
AS-14-S	1-M UNCOOLED IR TELESCOPE	UNKNOWN	7 DAYS	<1
AS-15-S	3-M AMBIENT TEMP IR TELESCOPE	2 ± 0.5°K	7 DAYS	<1
AS-20-S	2.5-M CRYO COOLED IR TELESCOPE	2±0.5°K; 20±1°K TELESCOPE	7 DAYS	<1
HE-15-S	MAGNETIC SPECTROMETER	3 ± 1°K	7 DAYS	<1

DEFINITION OF TECHNOLOGY REQUIREMENT | NO. RI, 13.1

1. TECHNOLOGY REQUIREMENT (TITLE): Solar Electric Propulsion | PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Guidance, Navigation, & Control

3. OBJECTIVE/ADVANCEMENT REQUIRED: Control of low thrust, accelerating planetary flights

4. CURRENT STATE OF ART: No system breadboards have been developed, analysis of requirements only.

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

Traditional GN&C methods associated with coasting systems use a sun-canopus reference system.

Solar electric propulsion systems must steer a thrust vector and will probably use a stellar aided inertial attitude determination system. The major requirements for the system are:

Communications link - probably the Deep Space Network, DSN
Large field of view digital sun sensor - off-the-shelf item
Star trackers - CCD's not available, image dissectors available
Gyro package - Lasers not available, gas bearing gyro available
Software - must be modified to compute thrust vectors

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Solar electric propulsion systems have higher specific impulse than conventional chemical propulsion systems. The requirements for GN&C are determined by SEP performance and mission parameters.
b. PL-09A - Mercury Orbiter
PL-16A - Ganymede Orbiter/Lander
PL-18A - Encke Rendezvous
PL-20A - Asteroid Rendezvous
c. GN&C system required to assure orbital precision
d. Software simulation and environmental testing required, including technology demonstration flight.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. RI, 13.1

1. TECHNOLOGY REQUIREMENT(TITLE): Solar Electric Propulsion — PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

Item	Option - Available Technology
Laser gyro	Conventional gyro with high MTBF such as Minuteman missile spherical gas bearing gyro
CCD star tracker	Image dissector star tracker made by Ball Bros.

8. TECHNICAL PROBLEMS:

The laser gyro and CCD star trackers are emerging technology. The laser gyro is under development by MSFC; the breadboards have been constructed - technology not ready.
CCD star trackers under development by companies such as Fairchild, not yet proven.
New DSN guidance software algorithms will be required to compute optimum thrust vector pointing angles as a function of time.
Tradeoffs required between ground and on-board processing and control.

9. POTENTIAL ALTERNATIVES:

Unknown

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Items in 7 (above) under development for military applications - status unknown

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

See RI 14.1

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RI, 13.1

1. TECHNOLOGY REQUIREMENT (TITLE): Solar Electric Propulsion PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Laser gyro					Estimated available														
2. CCD star Tracker			Estimated available																
3. Software																			
4. Breadboards/Testing*											* Using available technology								
5. Engineering Model/ Testing*																			
APPLICATION																			
1. Design (Ph. C)							NOTE: Technology need date leave minimal development time for emerging technology items. Recommend using available technology items.												
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					▼													
NUMBER OF LAUNCHES							2					2	2			1	1	8

14. REFERENCES:

1. Discussion among Jim Cake and Bruce LeRoy, Lewis Research Center, and P. R. Fagan, Rockwell International, Nov. 18, 1974.
2. Letter from T. N. Edelbaum, and J. J. Deyst, Jr., Charles Stark Draper Laboratory, Inc., to H. Ikerd, GDCA, December 18, 1974.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RI, 13.2

1. TECHNOLOGY REQUIREMENT (TITLE): Structures/Mechanism PAGE 1 OF 5

2. TECHNOLOGY CATEGORY: Guidance, Navigation & Control

3. OBJECTIVE/ADVANCEMENT REQUIRED: Docking in a Mars orbit

4. CURRENT STATE OF ART: Studies and analysis to define mission. Breadboard of potential rendezvous systems have been constructed. These are applicable to Mars mission. HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

Five mission sequences which support orbital rendezvous have not been performed under conditions anticipated for the Mars Surface Sample Return (MSSR) mission; they are:

1. Ascent of the Mars Ascent Vehicle (MAV) from the surface to the rendezvous orbit.
2. Initial rendezvous, in which earth based control moves the orbiter to the MAV orbit.
3. Terminal rendezvous during which the orbiter closes on the MAV under control of an orbiter rendezvous radar.
4. Docking during which the orbiter & MAV couple, and
5. Sample transfer to the earth return vehicle.

(continued on page 4)

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a) A Mars Surface Sample Return science workshop was conducted NASA Headquarters on June 11 and 12, 1974, at which the Mars orbital rendezvous mode was endorsed as the favored approach from the standpoint of controlling back contamination.

b) PL-01-A, Mars Surface Sample Return

c) Rendezvous rather than direct return from a Mars lander requires less cost and weight for Mars ascent and Mars entry vehicles, and permits an increase in size of science sample.

d) Software-Laboratory simulation - 7
Components-space environment test-5
Systems/Subsystems-Space environment test & simulation-7

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(see d above)
TO BE CARRIED TO LEVEL ___

1. TECHNOLOGY REQUIREMENT(TITLE): Structure/Mechanisms

7. TECHNOLOGY OPTIONS:

a. A number of rendezvous radars have been developed. The most favored appears to be a MSFC sponsored laser radar which is in its third generation breadboard at ITT. The Nd:YAG being developed by WPAFB could be adapted to the rendezvous laser radar with technology transfer and make higher power available.

b. An alternate approach not requiring rendezvous and docking is described in (9) below.

8. TECHNICAL PROBLEMS:

a. Orbit determination in the presence of an anomalous Mars gravity field. Field has been partially mapped by Mariner 9 orbiter but does not allow accurate state prediction for Mars Surface Sample Return type orbits.

b. Software requirements, see C 19.1

9. POTENTIAL ALTERNATIVES:

Reference 2 states that launching the Mars Surface Sample and an integrated orbiter and earth return vehicle into Mars orbit is simpler and more reliable than launching the sample into orbit for subsequent transfer to the Mars orbiter integrated as an earth return vehicle, as required for Mars orbiter rendezvous modes.

(continued on page 5)

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

No current hardware developments, studies only.

Technology transfer of most items from Viking Lander and Orbiter programs possible.

EXPECTED UNPERTURBED LEVEL 3

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Radar/laser designs

b. Software programs

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. RI, 13.2

1. TECHNOLOGY REQUIREMENT (TITLE): Structure/mechanisms

PAGE 3 OF 5

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis & Requirements	—																		
2. Breadboards/Testing		—	—																
3. Engineering Model/ Testing				—	—														
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)							—												
2. Devl/Fab (Ph. D)								—											
3. Operations																			
4.																			

NOTE: Technology transfer available from Viking and Apollo-LEM programs.

Software requirements must be integrated into schedule, see C 19.1.

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE							▼											
NUMBER OF LAUNCHES									1									1

14. REFERENCES:

1. A Feasibility Study of Unmanned Rendezvous and Docking in Mars Orbit, Final Report, Vol. I and II, Martin Marietta Corp., JPL 953746, September 1974.
2. Mars Sample Return through parking orbit, W. L. Weaver & W. L. Darnell, LaRC, and H. N. Norton & L. D. Jaffe, JPL, Aeronautics & Astronautics, Jan. 1975.
3. Technical discussion between W. L. Weaver, Langley Research Center, and P. R. Fagan, Rockwell International, November 7, 1974.
4. Automated Mars Surface Sample Return (MSSR) Mission Concepts for Achievement of Essential Scientific Objectives, W. L. Weaver, LaRC, and H. N. Norton and W. L. Darnell, Jet Propulsion Laboratory.
5. Letter from W. T. Scofield, Martin Marietta Aerospace, to H. Ikerd, GDCA, December 11, 1974.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RL 13.2

1. TECHNOLOGY REQUIREMENT (TITLE): Structures/Mechanism PAGE 4 OF 5

5. Description of Technology - continued

The mission as presently defined in Reference 1, requires that the MAV achieve an orbit within predictable tolerances after launch from a remotely pointed platform.

Earth-based tracking with orientation sensed by the lander inertial reference determines the position of the lander on Mars before launch.

The first stage is controlled with a simple open-loop rate gyro guidance system.

The earth is established as a pointing reference using Earth tracking and command links. The other reference is the sun, as detected by MAV sun sensors.

By means of Earth calculated commands the two vehicles are pointed at each other and the orbiter radar locks on the MAV transponder.

The orbiter executes a closing maneuver when the MAV is within a reasonable slant range using retrothrusting burns. This closing control is provided by range rate versus range relationships built into the orbiting computer.

Docking begins when the orbiter and MAV are at close range. The orbiter goes into three axis control.

The pointing accuracy of the orbiter rendezvous radar and MAV transponder must hold line of sight pointing to within ± 0.5 deg. of vehicle axis. A docking cone is used for sample transfer.

Potential Alternatives (Continued)

The entire entry and landing sequence is automatic. The entry program is received from Earth prior to entry, and a computer in the Earth Return vehicle (ERV) issues the required commands.

A two-way communication link with the Mars Lander Module (MLM) will allow Earth-controllers to receive surface environment data and to command the go-ahead for the sample-acquisition sequence, which will be totally automated The Viking-type sampler boom and scoop will proceed to sample at a time designated in the command, and sensors will indicate discrete sampling actions. Launching the sample and integrated orbiter/ERV into orbit is simpler and more reliable than launching the sample into orbit for subsequent transfer to the orbiter/ERV which is required with the Mars Orbital Rendezvous (MOR) modes The Mars ascent vehicle (MAV) which will launch the ERV to orbit has a two-stage solid propellant propulsion system; the first stage is 3-axis stabilized by means of a guidance package whereas the second stage is spin-stabilized. The second stage is aligned and spun up by the attitude control system on the first stage just prior to orbit insertion. Essentially all velocity losses are sustained during first stage thrusting, and the second stage thrusts horizontally for insertion. The ascent program is received from Earth before launch, and the computer on the ERV controls all operations.

The ERV establishes two-way communications with Earth after MAV separation. The ERV is designed to function for a year as a Mars orbiter and then return the sample to earth.

The potential disadvantages of this direct return mission alternative includes the following:

1. Controlling the contamination of the return spacecraft by possible Mars biota is more difficult;

2. Significantly heavier Mars lander and ascent vehicles are required;

3. Getting into an orbit at Mars from which an accurate Earth return trajectory can be initiated approaches the complexity of the rendezvous.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RL 14.1

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 5

Primary Solar Electric Propulsion

2. TECHNOLOGY CATEGORY: Propulsion

3. OBJECTIVE/ADVANCEMENT REQUIRED: 10,000 hour Operational Life

4. CURRENT STATE OF ART: Two thruster engineering models have been made and are undergoing testing. Power processor units are breadboarded for testing.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Thruster Technology

Two engineering models of 30 cm diameter thrusters have been built; they are:

EMT #701 - Calibration & endurance testing (on-going)

EMT #702 - Structural qualification testing (completed October 1974).

The 700-series design has been improved to include a two point gimbal interface; this resulted in the 800-series. Modifications to reduce discharge chamber sputter erosion will result in a 900-series design.

	Requirements	State of Art
Application	Defined by Lewis Research Center	Results of testing EMT #701 &EMT702
Type	Mercury Ion	Mercury Ion
Specific Impulse	3000 Sec	2950 Sec

(Cont. pg. 4)

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a) Requirements defined for planetary missions

b) PL-18A Encke Rendezvous (PL-26)
PL-09A Mercury Orbiter (PL-13)
PL-20A Asteroid Rendezvous (PL-28)
PL-16A Ganymede Orbiter/Lander (PL-23)

c) I_{sp} of 3000 is result of optimizing thrust for available power.

d) Space testing of operational prototype.

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TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. RI 14.1

1. TECHNOLOGY REQUIREMENT(TITLE): Primary Solar Electric Propulsion

7. TECHNOLOGY OPTIONS:

The principal option is in the selection of power processor unit (PPU) switching device (transistor or SCR). The transistor PPU provides higher efficiency, fewer parts and lighter weight. The SCR provides higher power per inverter. A secondary option is the PPU packaging concept; louver, heat pipes or a combination of both.

8. TECHNICAL PROBLEMS:

1. Long term internal erosion (sputtering) of thruster #701 shows a life of about 7000 hours. Analysis and accelerated tests shows that 20,000 hours can be attained using the modifications planned for the 900-series design.

(continued on page 5)

9. POTENTIAL ALTERNATIVES:

Xenon and Argon propellants can be used in the present thrusters with a feed system modification. However, penalties are incurred in the thruster, PPU and propellant storage. Cesium thrusters are not available at the 30 mlb thrust level.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

1. Operational prototype design/construction to be initiated middle 1975 (Lewis Research Center)
2. MSFC feasibility investigation

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

Unknown

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RI, 14.1

1. TECHNOLOGY REQUIREMENT (TITLE): Primary Solar Electric Propulsion

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Engineering Model tests	- -	- -	(on going)																
2. Design Operational Prototype	—	—																	
3. Build Operational Prototype		—	—																
4. Space Test Operational Prototype			—	—															
5.																			
APPLICATION																			
1. Design (Ph. C)					—														
2. Devl/Fab (Ph. D)						—													
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					▼													
NUMBER OF LAUNCHES							2					2	2			1	1	8

▼ Technology Need Date

REFERENCES

1. Extended Definition Feasibility Study for Electric Propulsion Stage, Rockwell International Corporation, SD73-SA-0132.
2. Technical Discussions with Dave Byers and Bruce Banks, Lewis Research Center, November 8, 1974.
3. Status of 30 cm Mercury Ion Thruster Development, J.S. Soney, Lewis Research Center and H. J. King, Hughes Research Laboratories, Malibu, California, NASA TM X-71603.
4. Solar Electric Propulsion Thrust Subsystem Development, T. D. Masek, Jet Propulsion Laboratory, Technical Report 32-1579, March 15, 1973.
5. Ion Propulsion Flight Experience, Life Tests, and Reliability Estimates, J. H. Molitor, Hughes Research Laboratories, Malibu, California, Presented to AIAA/SAE Propulsion Conference, November 5-7, 1973.

(Cont'd. on page 5)

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RL 14.1

1. TECHNOLOGY REQUIREMENT (TITLE): Primary Solar Electric Propulsion

5. DESCRIPTION OF TECHNOLOGY - continued

	Requirements	State of Art
Efficiency at full thrust	72%	71.6%
Input power	2630 watts	2630 watts
Throttle range	2:1 min 5:1 goal	5:1 demonstrated
Lifetime	10,000 hours over entire range of environmental constraint of near earth and planetary conditions; zero to two suns, and Shuttle and Titan-Centaur environmental envelope.	7500 hours have been demonstrated. Qualification testing on Titan-Centaur and Shuttle vibration envelope. Thermal tested over range of zero to two suns.
Power Processor Technology		
Efficiency	92% efficiency at full thrust and full input power.	1. SCR switch, thermal-vacuum breadboard developed by TRW is under test. This system has demonstrated 84% efficiency and weighs 100 lb. A follow-on breadboard has demonstrated 91% efficiency but projected TVBB weight is 125 lb. 2. Transistor switch, thermal vacuum breadboard (TVBB) built by Hughes to be delivered January '75. Projected efficiency is 91% $\pm$ 1% and weight is 52 lb.
Weight	50 pounds	
Thermal-vibration specifications	Same as thruster	
Life	10,000 hours	
Reliability	0.96	
Power Input	$\gtrsim$3 kw	

(continued on page 5)

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RI, 14.1

1. TECHNOLOGY REQUIREMENT (TITLE): Primary Solar Electric Propulsion

5. Description of Technology - continued

	Requirements	State of Art
Input voltage	2:1 voltage swing	2:1

Note: Assessment of two state-of-the-art power processors required before future decisions can be made. Approximately first quarter 1975.

8. Technical Problems - continued

2. Ion beam focusing at the end of life (unknown at this time)

3. Reduction of neutral Hg atoms and double ions (not required to meet life or efficiency goals).

4. Power processor efficiency, electromagnetic interference, and thermal control.

5. Thruster/power processor switching.

6. Power processor bus line ripples < 1% under all conditions, without excessive weight penalties.

14. References - continued

6. Thruster and power processor design and test reports, Hughes Research Laboratories, 1969-1974.

7. Letter from J. H. Molitor, Hughes Research Laboratories, to H. Ikerd, GDCA, January 20, 1975.

8. Letter from R. M. Worlock, Electro-Optical Systems, to H. Ikerd, GDCA, December 18, 1974.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. RI. 14.2

1. TECHNOLOGY REQUIREMENT (TITLE): Auxiliary Ion Propulsion Thruster

2. TECHNOLOGY CATEGORY: Propulsion

3. OBJECTIVE/ADVANCEMENT REQUIRED: 20,000 hour operational life and 10,000 cyles restart capability

4. CURRENT STATE OF ART: Basic Hg technology feasibility has been demonstrated on SERT I and II. Hg thruster ground test has exceeded 9,000 hours and is continuing. (continued on page 4) HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Both mercury and cesium ion thrusters are designed for north/south stationkeeping for synchronous satellite. The mainline technology for auxiliary ion propulsion systems is presently based on an 8 cm mercury electron bombardment ion thruster. This thruster provides a nominal thrust of 1 mlb (with a thrust range capability of 0.5 to 2.0 mlb) at a specific impulse of 2950 seconds. Total propulsion system dry weight including thruster/gimbal assembly, propellant reservoir, and power processor unit is projected to be 22 pounds. The cesium thruster is also 8 cm dia and capable of 1 mlb thrust. Dry weight is 25 lb without cesium and cesium reservoir. Much smaller cesium units of 20×10^{-6} lb thrust were demonstrated on ATS-4 and ATS-5, and they used a bimetal closeable valve which opened and closed as a function of temperature change. The tests on the ATS-6 required a much higher flow rate than the bimetal valve could accommodate, and the valve was replaced with a one-shot valve as it was believed that surface tension during cool-down would negate the possibility of liquid creep. Liquid migration apparently did occur under cool-down and as a consequence the engines would not restart. Table 1, page 4 compares mercury and cesium thruster parameters. (continued on page 4)

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Long-life, high specific impulse stationkeeping thrusters are required for geosynchronous communications satellites.
b. CN-51-A International Communications Satellite
c. Cesium and mercury bombardment engines are high specific impulse devices. Mercury is baseline.
d. Space testing of operational prototype required.

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TO BE CARRIED TO LEVEL 7

1 TECHNOLOGY REQUIREMENT(TITLE): Auxiliary Ion Propulsion System

7. TECHNOLOGY OPTIONS:

a. Mercury - demonstrated most flight operating hours
b. Cesium
c. Argon
d. Xenon

Both mercury and cesium have been tested on auxiliary propulsion ion thrusters. Both the cesium and mercury require essentially the same amount of power. The mercury electron bombardment ion thruster has demonstrated substantially more flight operating hours than the cesium bombardment thruster. The mercury thruster has the capability of multiple thruster operation from a common propellant tank.

8. TECHNICAL PROBLEMS:

a. Cesium - operates at 17 v, below the sputtering threshold which makes it longer lived, and more reliable than mercury engines. Propellant tankage, complexity, and handling problems make cesium less attractive than mercury. ATS-6 has shown cesium to be electromagnetically compatible over wide RF band. The cesium thrusters tested on ATS-6 have demonstrated an apparent cesium migration problem in zero gravity that was not experienced in ground testing. A valve (reference part 5) needs to be developed and ground life/cycling tests continued. (continued on page 4)

9. POTENTIAL ALTERNATIVES:

Use European auxiliary propulsion mercury ion thrusters.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Unknown - no effort other than NASA's

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

Power processor unit electronics - silicon control rectifiers are viable alternatives to transistors.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. RI, 14.2

1. TECHNOLOGY REQUIREMENT (TITLE): Auxiliary Ion Propulsion System

PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. on-going thruster life test																			
2. Cycling test on BB syst.																			
3. Engineering model syst.																			
a. Development																			
b. Qual testing																			
c. Cycling life test																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

NOTE: Life tests cannot be shortened. Technology cannot meet first launch unless minimal time spent in Ph. C & D

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				▼														
NUMBER OF LAUNCHES					2	3			2	3	2	2			2	3	2	21

14. REFERENCES:

1. Discussion between Dr. R. Hunter, GSFC, and P. R. Fagan, Rockwell International, November 13, 1974
2. Discussion among B. Banks and D. Byers, Lewis R.C., and P. R. Fagan, Rockwell International, November 8, 1974
3. Letter from J. Molitor, Hughes Research Laboratories to H. Ikerd, GDCA, 30 Jan. 1975
4. Letter from B. Banks, Lewis R.C. to H. Ikerd, GDCA, January 10, 1975
5. Letter from R. Worlock, Electro-Optical Systems to H. Ikerd, GDCA, December 18, 1974
6. Letter from Dr. R. Hunter, GSFC, to H. Ikerd, GDCA, January 2, 1975

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
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6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

1. TECHNOLOGY REQUIREMENT (TITLE): Auxiliary Ion Propulsion Thruster

4. Current State of Art - continued

Two Hg thrusters were tested on SERTS II, operating 2175 hours and 3889 hours respectively. One thruster is currently operational after 207 restarts. Two cesium thrusters were tested on ATS-6, both units failed to restart.

5. Description of Technology - continued

Table 1.

	Mercury	Cesium
Diameter, cm	8	8
Thrust, mlb	1	1
Dry system weight without propellant and propellant tank, lb	19.5	25
Ground test demonstrated life, hours/cycles	9130/277	2600/433
I_{sp}, sec	2900	2500
Input power, watts	150	150
Vector angle capability (dual axis), degrees	10	3

A mercury thruster engineering model level development is scheduled for completion by the end of 1975. Basic requirements for this system are 20,000 hours life (cumulative hours of thruster operation) over a ten-year stationkeeping mission, 10,000 on-off operational cycles, and thrust vector control over ± 10 deg. in any azimuthal angle.

Current efforts on the cesium thruster at GSFC are to develop the required valve, and to continue life testing on the ground. Their is no funding visibility on the cesium thruster.

8. Technical Problems - continued

b. Argon - propellant tankage, complexity and handling make argon less attractive than mercury.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE 15.1

1. TECHNOLOGY REQUIREMENT (TITLE): Tracker/Field Monitor Assembly PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Attitude Control/Measurement

3. OBJECTIVE/ADVANCEMENT REQUIRED: Provide improved location and identification of guide field as well as increased sensitivity, tracking accuracy. Tracking error limited to 0.1 arc sec with $m_v = 12$ stars.

4. CURRENT STATE OF ART: Typically: Accuracy approximately 10 arc sec and sensitivity $m_v = 6$ stars.

See: JPL Stellar System (Reference 3) HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

Improvement in Star Tracking to Provide

- Tracking error signal output 0.1 to 0.3 arc sec.
- Pointing System Stability Rate 0.006 ARC SEC/SEC (PK. TO PK.)
- Sufficient Sensitivity to track $m_v = 12$ stars.

Prime Approach:

Sensing of stars located in a direction within a fraction of a degree (proposed 0.25°) of primary telescope pointing direction. Two stars in single F.O.V. required for 3 - axis pointing. Position resolution of all $m_v = 12$ stars within 0.5° field of view is needed to correlate guided telescope output to reference guide stars.

Alternate Approach:

Using 2 Star-Trackers pointed towards 2 guide stars separated by an angle excluding the F.O.V. capability of a single tracker. Errors will include measurement of single difference between trackers with telescope.

(cont'd on page 3)

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) The advantage of referencing a star within a small fraction of a degree off the primary telescope axis is that the Startracker can be rigidly mounted to the telescope body, eliminating (or at least minimizing) the problem of measuring the angles relating Star-Tracker axis and telescope axis. Tracking viewfield of Star-Tracker must be sufficiently large (~0.5°) to include at least two potential guide stars. Accuracy requirements are dictated by requirements of the primary telescope system. Sensitivity to Mv = 10 stars is necessary to assure high probability of a guide star within a small angle of telescope axis.

(b) Approximately 18 payloads will benefit by this technology including seven Astronomy Sortie Payloads, three automated astronomy payloads, five high energy astrophysics sortie payloads, and four high energy astrophysics automated payloads.

(c) This technology advancement will make possible at least double the number of valuable observations of faint stellar sources.

(d) The level of technological maturity required for this development is prototype model testing in a simulated environment.

TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE 15.1

1. TECHNOLOGY REQUIREMENT(TITLE): Tracker/Field Monitor Assembly PAGE 2 OF 4

7. TECHNOLOGY OPTIONS: (1) Prime Option - using single tracker with starfield matching feature fixed to the telescope

a) Tracking stellar image with image dissector (ID) using ID aperture edge-sensing as means of improving resolution.
b) Use of separate photomultipliers (PM) or solid-state detectors in conjunction with mirror or prism image splitters for multi-sensing.
c) Operation of ID or PM in either of above concepts, but electronically in a photon-counting mode; as a means of increasing sensitivity.
d) Charge coupled device (CCD) area array detector at image plane, operating with selectable f/number, focal length optics; programmable null-pointing coordinates; automatic star-field map matching (Reference: JPL "Stellar" System)

(continued on next page)

8. TECHNICAL PROBLEMS:

a) Primarily sensitivity to detect the faint stars it will be necessary to track.

Tradeoffs are
- Optics size
- Detector Sensitivities
- Electronic Mode (current level or photon counting)
- Offset Angle Capability

(continued)

9. POTENTIAL ALTERNATIVES:
a) Sensing of bright stars that may be far off the telescope axis - requires highly accurate means of measuring and controlling relative pointing directions of on-board components.
b) Earth - Based Beacon Sensing (laser or microwave) -- same requirement as above & continuous information on effective change in direction of reference.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:
a) RTOP No. 506-19-14 (ELACS) Extended Life Attitude Control System for Unmanned Planetary Vehicles.
b) ITT NASA Contract -- improved FW-4012 (W/6" photocathode), 3.4 rise distance (vs. 20 typical) -- aperture edge-tracking applications.
c) ITEK -- diff raction grating approach (inhouse)
d) Perkin Elmer -- Beam-splitting approach (inhouse)

(Continued on next page)

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:
a) Solid-State detector sensitivity improvement
b) Electronic Techniques development (for ID aperture edge-tracking and/or photon counting)
c) Highly accurate large-angle measurement (for off-axis reference sensing)
d) On-board software & processing capability for beacon-sensing option.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-15.1

1. TECHNOLOGY REQUIREMENT (TITLE): Tracker/Field Monitor Assembly PAGE 3 OF 4

5. DESCRIPTION OF TECHNOLOGY (Continued)

The state-of-the-art is exemplified by two current star tracker developments:

1) The STELLAR System, "Star Tracker for Economical Long Life Attitude Reference (JPL) uses charge coupled devices (CCD) in place of the image dissector, and is capable of 0.1 to 30° (variable) field of view, 11 m_v star sensitivity (with 4" diameter optics), 1 arc sec accuracy (worst case).

2) The HEAO Tracker (Hughes) uses the "photon counting and digital processing" method and is capable of a 2° × 2° field of view, 8 m_v star sensitivity (with 4" optics), and a calibration accuracy of 0.75 arc sec.

7. TECHNOLOGY OPTIONS (Continued)

(2) Alternate Option - using two physically separate star trackers

The two trackers may have any of the features in Item 7, (1) above. The severity of the errors introduced by the measurement of relative angle between the trackers and between those and the main telescope will depend upon the interconnecting structure, thermal effects, magnitude of the deviation angles between the optics, and the actual measuring machanism.

8. TECHNICAL PROBLEMS (Continued)

(b) Attainment of higher sensitivity required to utilize guide stars with Mv = 10. In the single-tracker option (No. 1) the F.O.V. must be sufficiently large to encompass at least two guide stars within the sensitivity capability of the detector.
(c) Time constant or bandwidth must be adequate.
(d) Ability to reduce acquisition and tracking time delays due to computation and response delays.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT (Continued)

(e) GE -- ASP PREC, Pointing System -- Study for GSFC
(f) Several NASA SRT Program Submittals (Nos. 506 - 18 -13, 506-19-12, 506-17-32)
(g) Stellar system being developed by JPL for AMES Research Center.

DEFINITION OF TECHNOLOGY REQUIREMENT

NO. GE 15.1

1. TECHNOLOGY REQUIREMENT (TITLE): Star Trackers

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis																			
2. Design Phase																			
3. Breadboard Test																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

TECHNOLOGY NEED DATE			△														TOTAL
NUMBER OF LAUNCHES					12	18	22	22	23	26	23	28	22	22	20	22	23	283

14. REFERENCES:

1. NASA/AMES c-141 AIRO Information Bulletin #6 (IB-6) 3/25/74.

2. "Video Inertial Pointing System for Astronomy Payloads". AMES RC., by J. V. Foster & D. R. Chapman.

3. JPL Memo No. 343-8-74-219, "Star Detection Capabilities of Charge Coupled Imaging Devices."

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-15.5

1. TECHNOLOGY REQUIREMENT (TITLE): Advanced Attitude Sensing System PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Attitude Control

3. OBJECTIVE/ADVANCEMENT REQUIRED: Provide attitude sensing to support knowledge of pointing to 0.001 degree accuracy. Concurrent advances are needed in ephemeris accuracy, to permit precise location of the satellite.

4. CURRENT STATE OF ART: Current systems are capable of 0.004-0.01 degree accuracy. Ephemeris accuracies of 50 meters can be attained with current technology.

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

(a) Advanced Earth Observation payload sensors will require pointing accuracies in the order of 10^{-3} degrees in order to permit precise correlation of high resolution multi-spectral data with earth surface features.

(b) Effect savings through hardware simplification and standardization of the attitude control subsystem.

(c) Current state of the art is typified by the PADS, or Primary Attitude Determination System that is accurate to 0.01 degree and uses strapped down inertial measurement and star detector. The Space Shuttle will be able to be located within 170 meters (RSS) at 100 nm altitude. Automated payloads such as EOS will be located within 50 meters. The Hughes STARS (Stellar Tracking Attitude Reference System) would utilize a single, inertially stabilized, gyro-less star tracker to accomplish 0.001° pointing.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) Current trends in the development of high-accuracy attitude determination systems are towards more stringent pointing accuracies, hardware simplification and more extensive use of on-board computers. The trend in pointing accuracy can be exemplified by Nimbus, ERTS, and EOS, which require 1.0, 0.7, and 0.01 degree, respectively. Significant reductions in the number of sensors can be realized through increased computational capability. The use of the computer also affords considerable flexibility of operation and thus the necessary versatility for subsystem hardware standardization.

(b) This technology will benefit most of the future Earth Observation automated payloads, particularly advanced operational satellites such as the Earth Resources Survey Operational Satellite (ERS-OS), EO-61A.

(c) Higher pointing accuracies, in the order of 0.001 degree are justified on the basis of increased resolution requirements and reduction in the amount of ground-based geometric correlation/correction.

(d) The technique will require thorough demonstration in ground simulation tests and on experimental satellites such as EOS prior to commitment to the operational satellite systems.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-15.5

1. TECHNOLOGY REQUIREMENT(TITLE): Advanced Attitude Sensing System PAGE 2 OF 4

7. TECHNOLOGY OPTIONS: The variables involved in this technology include:

(a) Type of inertial sensor and star sensor to be used.
(b) Degree of computational capability and type of computer.
(c) Centralized computer for all subsystems vs. dedicated computer.
(d) Software for each mission application.
(e) Drive electronics to translate computer instructions in terms of time-phased attitude control functions.
(f) Extent of ground-based versus on-board computation/data processing.

Tradeoffs are required concerning the optimum use of ground control points vs. knowledge of pointing, residual alignment errors and ephemeris accuracy.

8. TECHNICAL PROBLEMS:

1. Complexity of software requies new, versatile programming techniques.

2. Significant improvements in ephemeris accuracy beyond current state of the art may involve high operational complexity.

9. POTENTIAL ALTERNATIVES:

Autonomous navigation techniques such as those being developed by LaRC, using target correlation through coherent optical techniques may simplify the on-board system (see Reference 1). Payloads may use Navsat information for precision location.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

(a) Earth Observatory Satellite and Solar Maximum Mission Satellite plan to utilize this technology but with less stringent accuracy requirements.

(b) Related RTOP's are as follows:
502-23-41 Earth Oriented Attitude Reference
502-23-42 Inertial Components
(Continued)

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

Software technology advancements are a vital part of the subject technology; therefore, general software developments will impact this technology.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-15.5

1. TECHNOLOGY REQUIREMENT (TITLE): ADVANCED ATTITUDE SENSING SYSTEM

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT: (Continued)

502-23-43 Adv. Components for Precision Control Systems

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-15.5

1 TECHNOLOGY REQUIREMENT (TITLE): Advanced Attitude Sensing System PAGE 4 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analytical Studies	—																		
2. Software Development	—	—																	
3. Prototype Hardware		—																	
4. Ground Simulation		—																	
5. Space Qualification			—																
APPLICATION																			
1. Design (Ph. C)			—	—															
2. Devl/Fab (Ph. D)				—	—														
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE			△															
NUMBER OF LAUNCHES					1	1	1	1	1	1	1	1	1	1	1	1	1	13

14. REFERENCES:

1) "Feasibility Study of a Stellar Tracking Attitude Reference system - Final Report", June 1971, B. Klestadt, Hughes Aircraft Company, NTIS Accession No. N72-19717, NASA CR-119676.

2) "Definition of a Stellar Tracking Attitude Reference System Experiment for a Communication/Navigation Research Laboratory", March 1973, Hughes Aircraft Company, Report No. SCG 30112R, 30113R.

3) "Stellar Tracking Attitude Reference System - System Application Study", September 1974, B. Klestadt, Hughes Aircraft Company, Report No. SCG 40341R.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-16.1

1. TECHNOLOGY REQUIREMENT (TITLE): Transmission System for Planetary Entry Probe

2. TECHNOLOGY CATEGORY: Telemetry, Tracking and Command

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop a transmission system capable of penetrating through the atmosphere of Saturn, Uranus, or Jupiter, for data transmission to the planetary (bus) vehicle (e.g., Pioneer).

4. CURRENT STATE OF ART: A design concept has been postulated and modeled for a probe receiver, transmitter and antenna system for a Saturn/Uranus atmospheric entry probe.

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

Critical Parameters

The gathering of atmospheric data during entry of the probe in the planetary atmosphere is one of the primary goals of many advanced planetary missions in the NASA model. The required advancement in the state-of-the-art would consist of designing and experimentally testing the operation of transmission system(s) for operation in the atmosphere of Saturn, Uranus and Jupiter, considering the following parameters:

(a) Atmospheric gas constituents, density and spatial distribution
(b) Atmospheric dynamics, especially the turbulence characteristics
(c) Thermal plasma resulting in RF blackout.
(d) Synchrotron noise and thermal noise originating from the region of the planet.

(Continued on page 2)

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

It is possible that modest state-of-the-art advancements in transmitter and antenna design will be required to satisfy the desired high probability of mission success, given the uncertainties of the characteristics of the planetary atmospheres.

(a) Atmospheric constituents, turbulence, and pressure will affect choices of carrier frequency, modulation, and power levels needed to overcome attenuation. Uncertainty in Jupiter's helium to hydrogen ratio, for instance, is estimated at 18% and may be off by a factor of two.

(b) The radiation environment is very severe, as evidenced by the rates encountered in the Pioneer 10/11 spacecraft. That flight also established Jupiter as a significant source of energetic particles. This aspect will affect the selection of electronic components and their shielding and thermal design.

(Continued on page 2)

TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-16.1

1. TECHNOLOGY REQUIREMENT (TITLE): Transmission System for Planetary Entry Probe PAGE 2 OF 4

5. DESCRIPTION OF TECHNOLOGY: (cont'd)

(e) Nuclear radiation, cosmic, and thermal environments

(f) Uncertainty in the general geometry between the probe and the bus vehicle during fly-by probe entry.

Although the transmission system specifications have not been formulated as yet, the transmitter weight goal is typically less than 1.5 kilograms, power consumption not to exceed 100 watts, rate of a PCM convolutionally coded waveform will be 40-50 bits per second, reliability 0.998, operating life of 10 hours and storage life of up to 10 years. The maximum expected range is 10 Jupiter radii.

The current state of the art is characterized by conceptual designs based on communication link analyses which factor in the uncertainties of the planetary environment models current at the time.

6. RATIONALE AND ANALYSIS: (cont'd)

(c) Relative geometry between the probe and bus vehicle may pose special requirements on the antenna pattern and gain characteristics. Typically, the 1981 Pioneer Saturn/Uranus Flyby Mission requires 110 to 130,000 km communication range, with the trajectory chosen to limit the probe aspect angle to less than 10 degrees.

Benefitting Payloads

PL-11A Pioneer Saturn/Uranus Flyby

PL-13A Pioneer Jupiter Probe

PL-22A Pioneer Saturn Probe

(d) Level of Technological Maturity

The receiver, transmitter and antenna system should be breadboard-tested simulating the geometric and attenuation conditions expected to be encountered in the planetary environment. The effectiveness of the electronic component hardening concept should be verified, at least to the individual part (e.g., transistor) level.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-16.1

1 TECHNOLOGY REQUIREMENT(TITLE): Transmission System for Planetary Entry Probe PAGE 3 OF 4

7. TECHNOLOGY OPTIONS:

Key variables are:

(a) Carrier frequency: typically 0.4 to 1.0 GHz for the Saturn/Uranus Flyby mission. Power requirement is larger at 1 GHz.
(b) Beamwidth range up to 130° are considered. Power requirements increase with beamwidth.
(c) Modulation: tradeoffs include type of modulation (e.g., non-coherent F.S.K. versus P.S.K. with phase-lock loop reception).

8. TECHNICAL PROBLEMS:

The principal problem is the uncertainty in the characteristics of the planetary atmospheres.

9. POTENTIAL ALTERNATIVES:

(a) Design the transmission system with very large power margin, to account for unknown environmental conditions. Impact may be a significant increase in overall planetary vehicle weight and volume.
(b) Multi-channel design to incorporate several approaches tailored to various potential combinations of environments.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

The following programs related to planetary atmospheres are pertinent to this technology advance:

186-68-65 Pioneer Follow-on Mission Technology
185-47-66 Structure of Planetary Atmospheres
185-47-67 Planetary Atmospheres - Structure and Composition
185-47-68 Planetary Atmospheres Experiment Development
185-47-81 Theory and Models

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

None

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. GE-16.1

1. TECHNOLOGY REQUIREMENT (TITLE): Transmission System for Planetary Entry Probe — PAGE 4 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analyses																			
2. Math. Modeling																			
3. Model Design & Mfg.																			
4. Model Tests																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE					△													
NUMBER OF LAUNCHES						1	1			2								4

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE 16.4

1. TECHNOLOGY REQUIREMENT (TITLE): Memory Unit for On-Orbit Functions PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Telemetry, Tracking and Command

3. OBJECTIVE/ADVANCEMENT REQUIRED: Provide high capacity, compact, module and memory unit for payload functions for P/L checkout, subsystem support and experiment data storage.

4. CURRENT STATE OF ART: Magnetic bubble memories have demonstrated the required capability in the laboratory; adaptation to the specific shuttle application is needed. HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

(APPLICATION A) Specific Pallet-only sortie payloads require a large memory (500,000 word) size and quick access time (5 millisec.) to permit very detailed checkouts to be performed expeditiously, and to conduct complex (stellar) target acquisition and pointing operations without overloading the quick access memory. The available volume is $0.06m^3$.

(continued on page 2)

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) (APPLICATION A) The 500,000 word (32 bit) capacity and 5 millisecond access time requirements are based on SSPDA mission analyses for the checkout phase, initial target acquisition and pointing of large astronomical optical systems. Since each nominal sortie mission lasts 7 days, any savings in preparatory tasks such as checkout and initial acquisition will allow more time for actual experimentation.

(APPLICATION B) The large storage requirement for experiment data cited in (5) above assumes that the Tracking and Data Relay Satellite System will not be designed to offer maximum wideband data relay support for long periods (several days), to multiple simultaneous users.

(b) Specific payloads benefitting from this technology are AS-01S, 1.5meter IR telescope; and AS-04S, 1-m Diffraction limited UV telescope. Automated payloads such as advanced versions of the Earth Observatory Satellite, EO-08A will also benefit.

(continued on page 2)

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE 16.4

1. TECHNOLOGY REQUIREMENT (TITLE): Memory Unit PAGE 2 OF 4

5. DESCRIPTION OF TECHNOLOGY (Continued)

The state-of-the-art for Application "A" is summarized below:

Type of Device	Storage Capacity	Access Time	Volume M^3
Charge Coupled Device	8.4×10^6 Words	4 millisec. (max.) 2 millisec. (ave.)	0.01
Disc Memory	1.25×10^6 Words	12.5 millisec.	>1.06
Drum Memory	8.4×10^6 Words	16 millisec. (max.) 8 millisec. (ave.)	0.08
Magnetic Bubble	10^6 Words	3 microsec*	TBD
Floppy Discs	1.31×10^5 Words	8.4 millisec.	<0.06

* The 3 microsecond access time is expected from a Bell Laboratories experimental unit. (See Application "B" for a bubble memory by NASA-LaRC that is not designed for random access.

(APPLICATION B) High data rates and long periods of observation data in Earth and Ocean Physics will require storage of and accessibility to large quantities of digital data on-board the automated spacecraft or Spacelab. Typical of these requirements is the M.S.S. Imagery P/L OP-05S which requires the storage of 4.3×10^{10} bits during a 7-day sortie mission. Current high density magnetic tape is capable of storing up to 10^5 megabits per tape reel ; although this magnetic tape may be adequate in applications requiring merely the accumulation of data for return to the ground, its access time is not compatible with rapid on-board edit and multi-sensor correlation functions.

6. RATIONALE AND ANALYSIS (Continued)

(c) In application A, it is estimated that 6 hours of operation time will be saved through checkout diagnostic operations and initial acquisition of stellar targets.

(d) The technological development should be carried to the testing of an operational model (prototype) under actual orbiter ascent, descent and land conditions.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-16.4

1 TECHNOLOGY REQUIREMENT(TITLE): MEMORY UNIT PAGE 3 OF 4

7. TECHNOLOGY OPTIONS:

Technology improvements may be effected in any of the following memory storage systems:

(a) Disc memory - Recent developments make these systems highly reliable (e.g. incorporation of air bearings, sealed storage).

(b) Magnetic Domain (Bubble) Memory - This constitutes the most promising future method for low cost, large storage capacity, and high reliability data storage.

(c) Floppy Discs - These new devices compete very favorably with cartridge/cassette tape transports, as a low cost storage method.

The critical parameters that affect payload are access time, life, MTBF, power consumption, weight, vibration/shock/acceleration resistance and operating temperature.

8. TECHNICAL PROBLEMS:

(a) Limited volume capacity in the Payload Specialist Station or spacelab.

(b) High reliability operation after exposure to the boost environment of the Shuttle System.

(c) While magnetic bubble memories might offer viable solutions, the temperature range over which adequate performance margins can currently be achieved is limited.

9. POTENTIAL ALTERNATIVES:

Space Shuttle computer could be shared with the payload, however, this is required on a non-interference basis with respect to the primary mavigational and checkout functions of the Shuttle.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Reference 4 lists two pertinent programs in this area. It is expected that suitable storage components will be available through unperturbed technology advances, however, their application to the specific problem at hand may not be completed on time.

EXPECTED UNPERTURBED LEVEL 6

11 RELATED TECHNOLOGY REQUIREMENTS:

The development of mini-computers and micro-computers that will satisfy the increasing demands by a great variety of payloads will be relevant to the memory systems with which they must operate.

DEFINITION OF TECHNOLOGY REQUIREMENT

NO. GE 16-4

1. TECHNOLOGY REQUIREMENT (TITLE): Memory Unit

PAGE 4 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Detailed Requirements																			
2. Test of Avl'bl Systems																			
3. Breadboard Test																			
4. Prototype Test																			
5. Design modification																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE							△											
NUMBER OF LAUNCHES							2	2	2	3	1		1	1	1	1	1	15

14. REFERENCES:

1. "Magnetic Bubbles" - article by Andreq H. Bobeck and H.E.D. Scovil, Scientific American.

2. "Floppy Disc Drives", article by John A. Murphy, Modern Data.

3. "Boosting Reliability of Disc Memories", article by Roland Boisvert and S. S. Lambert, Electronics,

4. "Investigation of System Integration Methods for Bubble Domain Flight Recorders" prepared under Contract No. NAS1-12435 (in final review) and "System Analysis for Spaceborne/Airborne Magnetic Bubble Mass Memory", Technical Report AFAL-TR-270, dated October 30, 1974, prepared under Contract No. F33615-73-C-1103, by Rockwell International under contract to Microelectronics Group, Flight Instrumantation Division, Langley Research Center, NASA, Langley, Va., and the Air Force Avionics Laboratory, Air Force Systems Command, Wright-Patterson AFB, Ohio.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G. MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-17.1

1. TECHNOLOGY REQUIREMENT (TITLE): High Voltage Solar Array PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Electrical Power

3. OBJECTIVE/ADVANCEMENT REQUIRED: Increased reliability and decrease electrical subsystem weight through multi-kilovolt signal conditioning with circuits that are integral to the solar array.

4. CURRENT STATE OF ART: High voltage array system at voltage 100 VDC levels are well within the state of the art, as typified by the Communications Technology Satellite (Canadian) to be launched ~~in 1975.~~ HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

The electronic components (e.g. S.C.R.'s) required to perform the necessary switching function between solar cell blocks must be capable of blocking 15 kilovolts in the forward direction. The reliability associated with these devices must be sufficiently high to support missions of 5 to 10 years duration. With the exception of the high-reliability high-voltage switching devices, the technology for high voltage solar arrays is available and will improve with the development of high efficiency solar cells. The design of the solar array and its individual components must be able to withstand the high voltage levels (e.g., up to 15 KV) without voltage breakdown. The state of the art is 67 VDC on the Canadian Communications Satellite. A laboratory solar array at the Lewis Research Center has been operated at 1500 volts without problems (Reference #3).

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) The 15 kilovolt level for the switching devices is based on the requirements of advanced communication traveling wave tubes as required for the communications R&D prototype satellite (CN-01A).

(b) In addition to payload CN-01A, advanced geosynchronous satellites utilizing ion propulsion will benefit from this technology. The majority of these applications fall in the disciplines of Earth Observation and Communication/Navigation.

(c) Heavy, complex power conditioning equipment used in low voltage solar array systems significantly reduces the reliability of the system.

(d) This technology advancement should be carried to an experimental demonstration in an automated spacecraft or an early shuttle flight.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-17.1

1. TECHNOLOGY REQUIREMENT(TITLE): High Voltage Solar Array PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

An alternative to the high voltage SCR may be a high voltage electromagnetic vacuum relay of sufficiently small dimensions to permit integral accommodation with the solar array. Solid state control circuits are technology limited. Transistors and SCR's with capabilities beyond a few hundred volts are beyond the state of the art.

8. TECHNICAL PROBLEMS:

1. Interaction of array with charged particle environment (Reference #4).
2. Array handling at normal light levels.
3. High voltage SCR's with high reliability may not be feasible. SCR thermal dissipation on the solar array substrate has presented serious design limitations.
4. The design of the array to prevent voltage breakdown will be difficult in view of the light weight quality of the arrays and the possibility of sharp protrusions and discontinuities producing arcing. Shielding presents significant weight penalties.

9. POTENTIAL ALTERNATIVES:

Design using a larger number of lower voltage SCR's is possible.

Design with a higher bus voltage, up to the limit where voltage breakdown may present a hazard with conventional design practice.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP #502-24-17 "Solar Array Technology for Solar Electric Propulsion State" could be expanded in scope to also invetigate high voltage designs.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

Electrical power control component technology, high voltage level distribution systems.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-17.1

1. TECHNOLOGY REQUIREMENT (TITLE): High Voltage Solar Array

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analyses	—																		
2. Electrical Component Design		—	—																
3. Component Tasks			—																
4. Array Fabrication				—															
5. Array Ground Task					—														
6. Array Space Checkout					—	—													
APPLICATION																			
1. Design (Ph. C)						—													
2. Devl/Fab (Ph. D)							—												
3. Operations							—	—	—	—	—	—	—	—	—	—	—	—	
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					△													
NUMBER OF LAUNCHES					4	6	6	7	9	5	6	4	3	9	5	9	4	77

14. REFERENCES:

1) "Study High Voltage Solar Array Configurations with Integrated Power Control Electronics," Final Report, contract NAS-3-8997, General Electric Co.

2) "High Voltage Solar Array Experiments, Final Report, contract NAS-3-14364, The Boeing Company.

3) "High Voltage Solar Cell Power Generator System", by E. Levy, Jr., R. Opjordan, A. C. Hoffman, 10th IEEE Photovoltaic Specialists Conference.

4) "The Interaction of Spacecraft High Voltage Power Systems with the Space Plasma Environment", by S. Domitz and N. T. Grier, Proceedings of the Power Electronics Specialists Conference, June, 1974.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-17.5

1 TECHNOLOGY REQUIREMENT (TITLE): High Energy Density Battery PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Electrical Power

3. OBJECTIVE/ADVANCEMENT REQUIRED: Provide battery weight improvement in the order of 50%, for automated spacecraft missions of long duration.

4. CURRENT STATE OF ART: Nickel Cadmium batteries are capable of ten watt-hours per pound with very high reliability.

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

A goal of 25 watt-hours per pound or 55 watt-hours per kilogram* seems reasonable on the basis of laboratory tests of the Nickel-Hydrogen cell. Attainment of high reliability for long life applications is still a problem. The behavior of a Metal-Hydrogen battery under actual space operations and environment is in question, considering its early stage of development. For instance, laboratory tests have uncovered the problem of loss of electrolyte.

Higher energy densities are possible with Silver-Hydrogen cells; the disadvantages are shorter life times, silver migration, and water formation which dilutes the electrolyte and compilicates electrolyte management.

Other cell types under investigation are Silver Zinc and Nickel Zinc.

* Note: Energy density comparisons at 100% depth of discharge are: NiCd-30-40 watt-hr/kg, AgZn and AgH2-90-100 watt-hr/kg.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) The stated requirement is based on the high power utilization associated with spacecraft such as those for future communication/navigation applications and Earth observation applications where high power levels are maintained through the eclipse period of the orbit. Nickel Cadmium batteries can deliver 6 or 7 watt-hour/lb. after actual power derating (from 10 watt-hr./lb. capability. Therefore, to obtain 50% weight improvement would require 12-14 watt-hr/lb, which is estimated as a realistic output from a projected Nickel-Hydrogen battery after power derating.

(b) Specific payloads benefitting by this technology advance will be the geosynchronous satellites in Earth Observation and Communications.

(c) The advancement described herein is justified on the basis of the benefit associated with weight savings for large geosynchronous satellites. The intermediate Space Tug payload capabilities will limit the weight to geosynchronous orbit, thus making it desirable to attain the highest possible operational payload versus spacecraft weight ratio.

(d) The technology program should be carried to the demonstration of cyclic life in a temperature chamber for a total of cycles equivalent to 10 year operation

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TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT NO.17.5

1. TECHNOLOGY REQUIREMENT(TITLE): High Energy Density Battery

7. TECHNOLOGY OPTIONS:

Critical parameters in the NiH cell technology are: (a) The cell separator, which affect the permissible operating temperature, battery impedance, and operating voltage; (b) method of hydrogen sealing, which will affect leakage rate and thus battery life; (c) operating pressure of the hydrogen electrolyte, which may affect safety considerations.

Two important technology areas are the selection of hydride materials for use as H2 reservoirs in metal- H2 batteries, and the use of intercell electrolyte reservoir plates (IERP) for Ag-H_2 cells.

8. TECHNICAL PROBLEMS:

The main problem encountered in laboratory tests is the attainment of long life and number ot cycles. A potential problem in the initial operational period may be battery cost, compared with NiCd batteries.

Safety assurance under all operating conditions will be essential, particularly during the portion of the mission when the battery-carrying satellite is in the Shuttle Orbiter.

9. POTENTIAL ALTERNATIVES:

Some payloads requiring geosynchronous orbit may be able to be operated at significantly reduced power levels during the 36 minutes of eclipse. This will reduce the battery size.

10 PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

(A) RTOP-502-25-57 #W74 - 70319 "Deep Space Batteries" (JPL)
(B) Request 506-23-23 "Chemical Energy Conversion and Storage" (GSFC)
(C) Programs on NiH_2 cells conducted at Wright Patterson AFB
(D) Metal-Hydrogen Cell Program, NASA - LeRC.

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

None Identified

DEFINITION OF TECHNOLOGY REQUIREMENT

NO. GE 17.5

1. TECHNOLOGY REQUIREMENT (TITLE): High Energy Density Battery

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analyses																			
2. Separator Development																			
3. Cell Development																			
4. Cell Tests (Ground)																			
5. Battery Model																			
6. Battery Cycle Test																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					△													
NUMBER OF LAUNCHES						6	9	7	10	7	8	7	7	14	10	12	8	105

14. REFERENCES:

"Predicted Energy Densities for Nickel Hydrogen and Silver-Hydrogen Cells Embodying Metallic Hydrides for Hydrogen Storage", by Robert Easter, Lewis Research Center (Ninth Energy Conversion Engineering Conference, August 26-30, 1974).

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-18.1

1. TECHNOLOGY REQUIREMENT (TITLE): Subnanosecond Pulse Measurement & Correlation Detection; Pulse-to-Pulse Time Resolution, Small Time Differences PAGE 1 OF 5

2. TECHNOLOGY CATEGORY: Instrument Electronics

3. OBJECTIVE/ADVANCEMENT REQUIRED: Resolution of events to 0.1 nanosecond; accuracy of two pulses approximately 1 nanoseconds apart

4. CURRENT STATE OF ART: Some high energy astrophysics experiments operate with time resolution in the nanosecond region.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Triggered time measurements accurate to 0.1 nanosecond are required to achieve desired spectrometer experiment results. Oscilloscopes are presently available that can measure triggered time periods to a resolution of 20 picoseconds. Although these oscilloscopes are available, vast improvements in decreasing size and weight are required to obtain space compatible circuitry. Many of current balloon experiments operate with response times in the order of nanoseconds. Quick response circuits in the subnanosecond range enable measurements of time of flight of relativistic particles or of gamma rays as well as quick response triggering of anti coincidence and coincidence circuits. Current spatial detector timing measurements are accomplished to microseconds.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Characteristics of cosmic rays are determined by measurement of electron and positron spectra. Spectrometer experiments identifying particles in a magnetic field require accurate spatial detection which, in turn, requires time measurements to 0.1 nanosecond. Time of flight measurements between scintillators are also needed in order to determine which data is to be processed (i.e., in high energy experiments only data from short time of flight measurements will be processed).

b. The SO-01S, Dedicated Solar Sortie Mission, HE-15S, HE-08A, and HE-09A payloads require 0.1 nonosecond time measurements. See legend page 3 for payload names. (Particularly item SO-01S, Solar neutron experiment.)

c. Time interval resolution will be increased by more than 1000 times of previous measurements for spatial detection and ~10 times for time flight.

d. Technological maturity will be demonstrated when the miniaturized pulse measurement circuitry is analyzed in a space equivalent environment with other components. Laboratory tests on earth are satisfactory to prove attainment of desired capability.

TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT	No. C-18.1

1. TECHNOLOGY REQUIREMENT(TITLE): Subnanosecond Pulse Measurement & Correlation Pulse-to-Pulse Time Resolution, Small Time Differences

7. TECHNOLOGY OPTIONS:

The accuracy of pulse-to-pulse time resolution measurement could be relaxed if the time between pulses was increased. This would require a greater distance between either the scintillators or between the spatial detector plates, depending on which output was being measured. This would increase payload dimensions somewhat but would also increase accuracy of spatial detection of "rigid" particles or rays having small curvature in a magnetic field.

8. TECHNICAL PROBLEMS:

a. Pulses delivered to the timing device must have sufficient triggering level.

b. Device supplying triggering pulses must not introduce delay error.

c. Payloads using multiple timing circuits may require amounts of circuitry miniaturization which will be difficult to obtain.

9. POTENTIAL ALTERNATIVES:

Payloads requiring multiple timing circuits may reduce size and weight by using a single timing circuit in conjunction with recording circuits. When a signal to be timed is received on one channel the start and stop pulses may be recorded and the channel flagged. The timing circuit could then measure time duration between pulses on the flagged recorder channel. However, some gamma or cosmic ray instruments require a number of quick response circuits.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP: W74-70615, Definition of Solar Physics Experiments for Space Shuttle, Goetz Oertel
RTOP: W74-70646, Particle Astrophysics, Albert G. Opp
RTOP: W74-70647, Particle Astrophysics, F. B. McDonald

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Particle charge measurement by two independent counters shall not have an error greater than ±0.25 units of charge.
b. Spatial detector technology advancements required to obtain measurements of 0.1 mm.
c. Electron energy resolution of 1.5% at 10 GeV, 3.0% at 100 GeV and 4.5% at 1000 GeV.
d. Positive identification of positrons and electrons with good proton rejection.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C18.1

1. TECHNOLOGY REQUIREMENT (TITLE): Subnanosecond Pulse Measurement & Correlation Detection; Pulse-to-Pulse Time Resolution, Samll Time Differences PAGE 3 OF 5

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Trades & Analysis																			
2. Exp. Model Design & Fab.																			
3. Test and Evaluation																			
APPLICATION																			
1. Design (Ph. C)																			
2. Development/Fabrication (Ph. D)																			
3 Operations																			
						M_4						M_3							

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
TECHNOLOGY NEED DATE		T															
NUMBER OF LAUNCHES						M1 M2 M4	M1	M1	M1 M1 M2	M1 M1	M1 M1 M1	M1 M1 M3	M1 M1 M1	M1 M1 M2	M1 M1 M1	M1 M1	27

14. REFERENCES:

a. Summarized NASA Payload Descriptions, Level A Data, Automated Payloads, NASA PD; July 1974.

b. Summarized NASA Payload Descriptions, Level A Data, Sortie Payloads, NASA PD, July 1974.

c. Preliminary Payload Descriptions, Vol. I &II, Automated & Sortie Payloads, July 1974

d. Future Payload Technology Requirements Study, First Progress Review, GDC, August 1974, pages 55-57.

e. Oscilloscope + Microprocessor + LED + Display = a Whole New Ball Game, EDN, September 5, 1974, pages 88-91.

f. Superconducting Magnetic Spectrometer Experiment for HEAO Mission B, Part I, Space Science Laboratory, University of California, Berkeley, Luis W. Alvarez, Principal Investigator.

g. Introduction to Experimental Techniques of High Energy Astrophysics, H. Ogelman and J. R. Wayland, GSFC, 1970.

h. Tektronix 1975 Products, Beaverton, Oregon.

i. Comments, Andrew Buffington of UCB, 7 January 1975.

LEGEND

□ M_1 = SO-01S, Dedicated Solar Sortie Mission

● M_2 = HE-15S, Magnetic Spectrometer

M_3 = HE-08A, Large High Energy Observatory A

M_4 = HE-09A, Large High Energy Observatory B

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

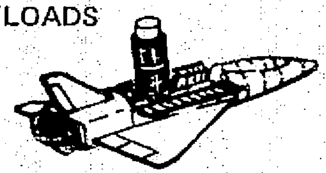
C.5

INSTRUMENT ELECTRONICS TECHNOLOGY NEEDS

ITEM	REQUIRED CAPABILITY	STATE OF ART
PULSE FORMING, DIFFERENCING CIRCUITS — RESPONSE TIME, NANOSECS	0.2	500 TO 2
TIME RESOLUTION, NANOSEC	0.1 TO 1	1000 TO 2
AMPLITUDE RESOLUTION	10^{-9}	10^{-7}

INSTRUMENT ELECTRONICS REQUIREMENTS FOR PULSE & CORRELATION DETECTION MEASUREMENTS

1980 SORTIES
QUICK-REACTION
HIGH-ENERGY
ASTROPHYSICS
PAYLOADS



MISSION REQUIREMENTS

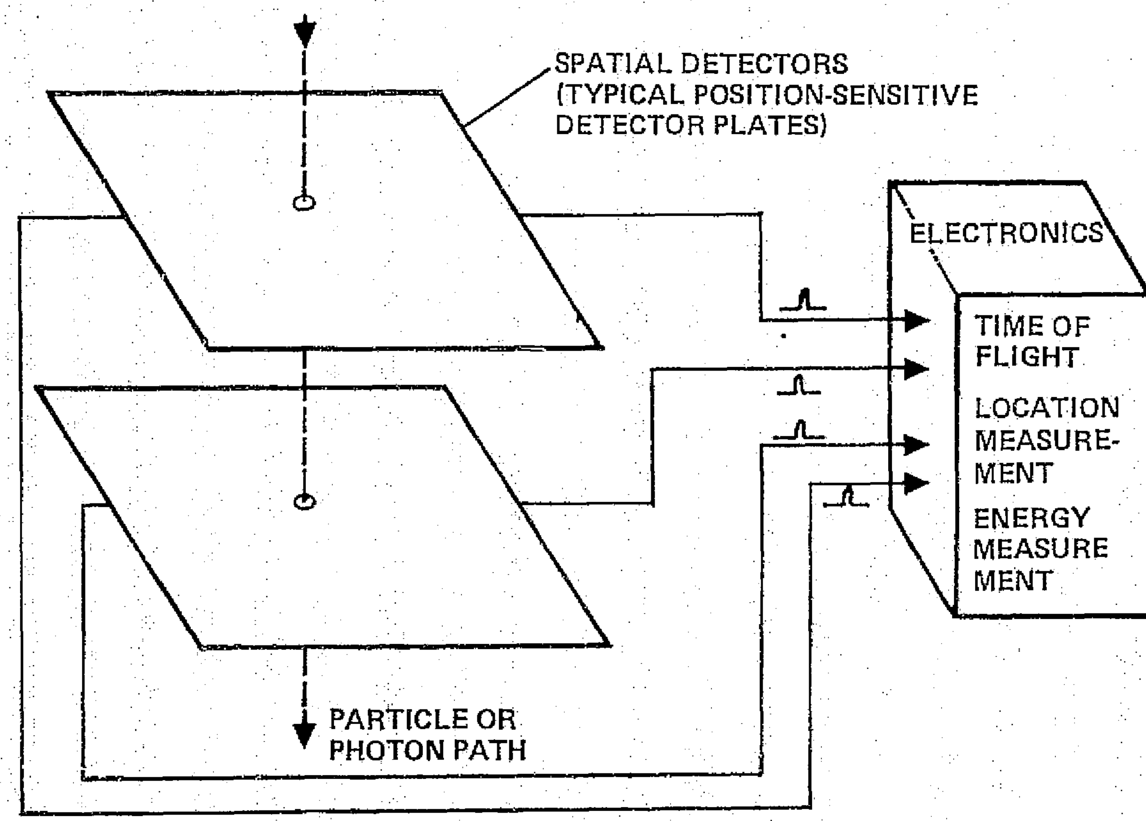
SEPARATE CHARGED PARTICLES FROM GAMMA RAY PHOTONS

ELECTRONICS REQUIREMENT

MEASURE PARTICLE & PHOTON TIME OF FLIGHT THROUGH SPATIAL DETECTOR LAYERS TO 0.1 TO 1 ns

DISCRIMINATION BETWEEN CHARGED PARTICLES & PHOTONS

- VELOCITY
- ANGLE OF ARRIVAL
- ENERGY MEASUREMENT



DEFINITION OF TECHNOLOGY REQUIREMENT NO. C. 18.2

1. TECHNOLOGY REQUIREMENT (TITLE): Cryostat/Magnet Electronics PAGE 1 OF 4
Decrease magnet charge/discharge time

2. TECHNOLOGY CATEGORY: Instrument Electronics

3. OBJECTIVE/ADVANCEMENT REQUIRED: Decrease charge/discharge time of magnet in order to meet all objectives of short duration mission.

4. CURRENT STATE OF ART: Cryostat/magnets are currently being charged in approximately 24 hours. Balloon borne magnetic spectrometers have been made.

HAS BEEN CARRIED TO LEVEL 6

5. DESCRIPTION OF TECHNOLOGY

The charge/discharge time of the superconducting magnet should be decreased by an order of magnitude from the 24 hours presently required in order to optimize the number of observations completed in a short duration mission. (If safety regulations permit it, the Space Shuttle Orbiter could take off with the superconducting magnet already energized.) Using present technology, a 7 day mission would be limited to approximately 4 days of actual information gathering. The 24 hour charge/discharge time has no significant effect on long term (1 year) missions with automated (free flyer) vehicles.

A larger charge/discharge time enables safer charge and discharge cycles.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. The cryostat magnet is used in experiments to provide the magnetic flux required to bend the trajectory of charged particles. Use of a cryostat magnet rather than a conventional copper wire magnet was determined by the substantial power savings offered by the cryostat magnet which, when charged, does not require a continuous source of energy. Since two magnets are required to eliminate the satellite dipole moment, and cancel the fringe magnetic field, the power savings are even more impressive. Use of a superconducting magnet coil also provides improvements in stored field strengths when compared to ordinary copper wire magnets.

b. HE-09-A, Large High Energy Observatory B; HE-12-A, Cosmic Ray Laboratory; and HE-15-S, Magnetic Spectrometer, make use of a superconducting magnet assembly in their magnetic spectrometers.

c. Shorter charge/discharge cycles increase maximum observation time on short missions. Automatic foolproof charge/discharge cycles also improve safety.

d. Level of technical maturity is demonstrated when a supercooled dual magnet system has been successfully cycled several times during mission simulations in vacuum tanks via externally commanded automatic circuitry.

TO BE CARRIED TO LEVEL 10

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DEFINITION OF TECHNOLOGY REQUIREMENT NO.C, 18.2

1. TECHNOLOGY REQUIREMENT(TITLE): Cryostat/Magnet Electronics PAGE 2 OF 4

Decrease magnet charge & discharge time

7. TECHNOLOGY OPTIONS:

a. The charge/discharge time of the cryostat magnet is determined by the amount of energy stored in the magnetic field. A substantial charge/discharge time reduction could be obtained by reducing the energy stored in the magnetic field. However, a corresponding increase in the accuracy of spatial detection electronics would be required to obtain the same experiment results.

b. The charge/discharge time of the superconducting magnet could also be decreased by increasing the charging current delivered to the magnet. Unfortunately, unless current density and/or superconducting material strength of the magnet are improved, the magnet size would have to be increased.

c. Trade off between safety, risk and time. More positive monitoring and control is required for shorter charge and discharge cycles.

8. TECHNICAL PROBLEMS:

a. The major problems are in increasing the magnets current density and increasing the strength of the superconducting material.

b. Necessity to avoid internal heating within the cryostat device during charge; during discharge energy in the magnetic field would need to be dissipated through diodes in a resistor bank.

c. Weight and size of cooling and coil charging circuitry.

d. Hazards of runaway energy dissipation. (Cont'd on Page 4)

9. POTENTIAL ALTERNATIVES:

a. Investigation into supercooled superfluid helium needs to be accomplished as well as investigation of coil materials at higher temperatures. Lower helium temperature may provide a higher safety factor.

b. Foolproof activation of supercooled magnets by means of proven software routines and a ruggedized special purpose computer may be necessary to reduce hazard if a quick charge/discharge cycle is required.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

W74-70389 (502-10-02) Research in Magnetics and Cryophysics, James C. Laurence, 216-433-4000. (Indicates studies to achieve intense magnetic fields with minimum mass requirements are being continued.)

EXPECTED UNPERTURBED LEVEL 6

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Accurate control circuitry is required to maintain the magnetic field of the two airborne magnets at the same strength to prevent satellite from becoming a dipole and also to prevent introduction of error in other experiments.

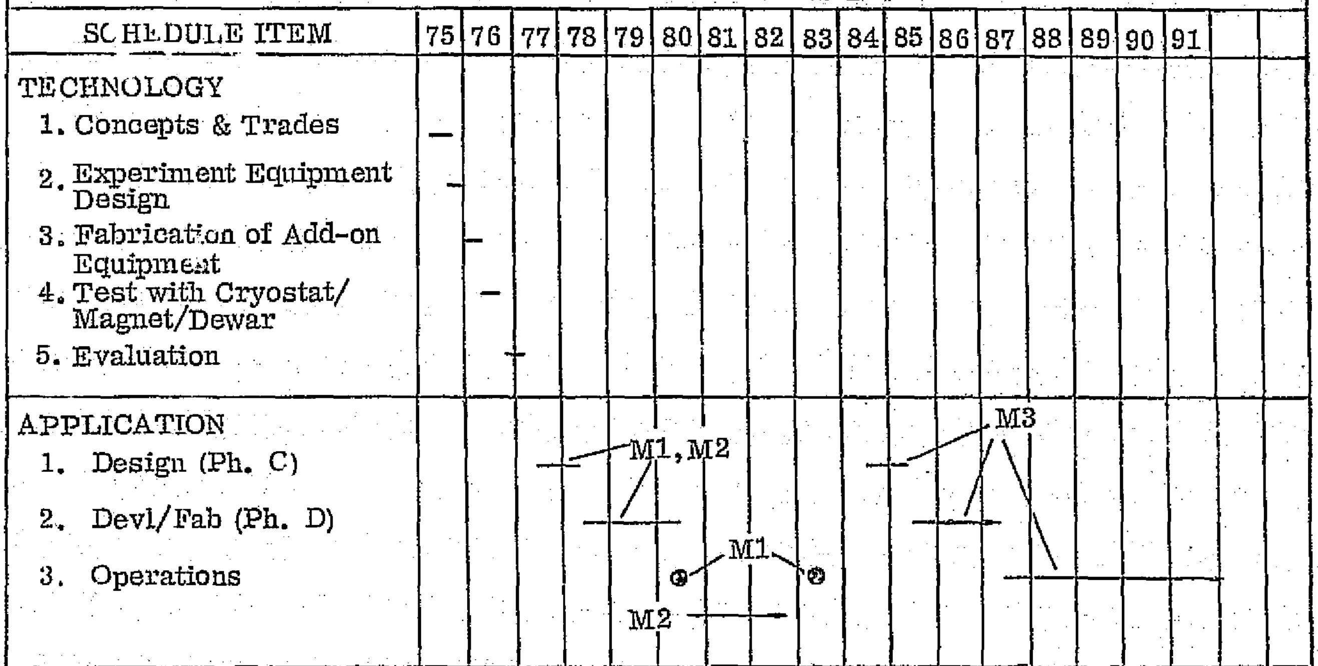
b. Cryogenic cooling and reliquification of helium will avoid heating of superconducting coils and always maintain coils within LHe.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C, 18.2

TECHNOLOGY REQUIREMENT (TITLE): Cryostat/Magnet Electronics PAGE 3 OF 4
(Decrease magnet charge & discharge time)

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR



13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		TOTAL
TECHNOLOGY NEED DATE			T																
NUMBER OF LAUNCHES						M1 M2			M1				M3						4

14. REFERENCES:

(See Page 4)

Legend:

M1 = Sortie Flight of Magnetic Spectrometer (HE-15-S)
M2 - Automated Flight of Magnetic Spectrometer (HE-09-A)
M3 - Cosmic Ray Lab (with advanced Magnetic Spectrometer (HE-12-A))

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C. 18.2

1. TECHNOLOGY REQUIREMENT (TITLE): Cryostat/Magnet Electronics PAGE 4 OF 4

Decrease magnet charge & discharge time

8. TECHNICAL PROBLEMS: (Cont'd)

e. Quicker charge and discharge cycles have higher hazards.
f. Liquid helium is diamagnetic and tends to form bubbles around super conducting magnetic coils.

. REFERENCES.

a Summarized NASA Payload Descriptions Automated Payloads, Level A Data, NASA PD, July 1974, pages 52, 53, 58, and 59.
b. Summarized NASA Payload Descriptions, Sortie Payloads, Level A Data, NASA PD, July 1974, pages 104 and 105.
c. Preliminary Payload Descriptions, Vol. I, Automated Payloads, July 1974, pages 2-103 thru 2-130.
d. Preliminary Payload Descriptions, Vol. II, Sortie Payloads, July 1974, pages 2-29 thru 2-56.
e. Part 1, Superconducting Magnetic Spectrometer Experiment for HEAO Mission B, 15 February 1972, University of California, Berkley, California.
f. Performance Review No. 3 - Plasma Physics and Environmental Perturbation Laboratory, 13 October 1972, TRW Systems, Redondo Beach, California.
g. "Superconducting Magnet and Cryostat for a Space Application" and "Low Heat Leak Leads for Intermittent Use", G. F. Smoot, and W. L. Pope, Vol. 20, Advance in Cryogenic Engineering (1974).

Rev. 3 December 1974

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C.18.5

1. TECHNOLOGY REQUIREMENT (TITLE): Filter for Gravity Grad- PAGE 1 OF 3
iometer Analog/Digital Filtering - Approach theoretical measurement accuracy

2. TECHNOLOGY CATEGORY: Instrument Electronics

3. OBJECTIVE/ADVANCEMENT REQUIRED: Filter analog signals to such a degree that 19 bit analog to digital conversion accuracy may be obtained. The signals are expected to be obtained from 4 mesa accelerometers. If signals are digital, a computer programmed filter is applicable.

4. CURRENT STATE OF ART: Circuitry for measurements with 12 bit accuracy are available. Current gradiometer designs have achieved 1.0 EU* accuracy.

HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY The
The gradiometer is expected to provide gravity measurements with an accuracy of 0.01 EU* in the background field of the earth of 3000 EU.* To accomplish this accuracy the output of the gravity gradiometer must be read to 19 bits of accuracy. This requires the gradiometer output to be very accurately filtered in order to suppress signals arising from system noise and from components of the nutation frequency occurring at the signal frequency. Current state of the art analog filters do not have this accuracy. The filtered signal must then be digitized to an accuracy of 19 bits. Analog to digital conversion of 12 bits can be accomplished with present state of the art.

*1 EU = 1 Eötvös unit = 10^{-9} gal/cm where 1 gal = 1 cm/sec^2

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Due to varying amplitude of gravity gradients with altitude, the satellite orbit should be as low as satellite drag will allow. The nominal altitude of 300 km was chosen. At this altitude the gravity gradiometer output would have to be measured within .01 EU to obtain mission objectives, thus requiring 19 bits of data to achieve desired measurement accuracy.

b. The gravity gradiometer experiment is scheduled to be conducted on the OP-02A Gravity Gradiometer payload.

c. Resolution of earth subsurface mass distribution boundaries are presently on the order of 1000 km or more. The proposed gravity gradiometer measurements to an accuracy of 19 bits (.01 EU) will provide boundary resolutions to approximately 100 km and permit earth's gravity field and geoid to be measured with a spatial resolution of 1 or 2 degrees and 0.1 meter in height.

d. The extension of the capability of current operational model(s) will satisfy this technology requirement.

TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-18.5

1. TECHNOLOGY REQUIREMENT(TITLE): Filter for Gravity Gradiometer Analog/Digital Filtering – Approach theoretical measurement accuracy PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

a. Rather than trying to filter out frequencies that do not divide the data frequency evenly a system of measuring these errors and subsequent correction of the digitized data may be more efficient. This increases the satellite data processing requirements.

b. Since the earth's gravitational field changes very slowly, high speed digital sampling and digital reconstruction of the gradiometer output waveform is an option that should be further exploited.

c. A constant bias may be used to remove earth's 3000 EU signal, then only 12-bit accuracy is needed.

8. TECHNICAL PROBLEMS:

a. Filtering and digitizing the gradiometer output signal to 19 bit accuracy require extremely accurate and stable electrical component characteristics. In addition electrical noise generated by the components could also introduce error into the digitized output signal. Different filtering is needed for different gradiometers particularly where instrumental errors need to be removed.

b. In order to prevent filtered frequency shifts, the electronic circuitry would have to be in a thermal controlled thermal environment.

9. POTENTIAL ALTERNATIVES:

a. Digital filtering of the gradiometer output is most likely and enables instrumental error correction flexibility.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

No advance will be made since only NASA has the 0.01 EU requirement.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Once the analog filtering of the gradiometer output is completed the analog to digital converter will have to be accurate to at least 19 bits. (If digital output, computer program used for detection.)

b. Calibration of the nutational frequency would have to be accurate and stable in order to prevent harmonics from passing through the analog filter and being digitized.

c. Dynamic errors (alignment, etc.) would have to be eliminated.

Rev. 3 December 1974

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-18.5

1. TECHNOLOGY REQUIREMENT (TITLE): Filter for Gravity Gradiometer Analog/Digital Filtering - Approach theoretical measurement accuracy PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Theoretical Analysis																			
2. Filter Concepts and Trades																			
3. Experimental Filter Programming																			
4. Test with simulated signals																			
5. Evaluation																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE			T															
NUMBER OF LAUNCHES						1												1

14 REFERENCES:

a. Summarized NASA Payload Description, Automated Payload, Level A Data, NASA PD July 1974, pages 104 and 105.

b. Preliminary Payload Descriptions, Vol I, Automated Payloads, July 1974, pages 6-19 thru 6-37

c. Earth Physics Gravity Gradiometer Study, JPL Report No. 760-70 (J. A. Gardner Team Leader, E. J. Sherry Study Leader), May 1972.

d. AFCRL-TR-0535 Application of Kinematical Geodesy for Determining the Short Wavelength Components of the Gravity Field by Satellite Gradiometry, GSFC Science Report 201, Ohio State, George B. Reed, March 1973

e. GSFC Report X-632-74-286 On Estimating Gravity Anomalies from Gravity Gradiometer Data, P. Argentiero, R. Garza-Robles, Sept. 1974

f. Review of Gravity Gradiometer Techniques for Geodesy, Hughes report RR 469, R. L. Forward, May 1973.

1. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G. MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C19.1

1. TECHNOLOGY REQUIREMENT (TITLE): Onboard Software for payload monitoring control, checkout, redundancy management and rendezvous and docking.

2. TECHNOLOGY CATEGORY: Software

3. OBJECTIVE/ADVANCEMENT REQUIRED: Achieve a significant reduction (4:1) in software cost to reduce projected software cost to 10% of total payload cost. Reductions in software costs must be achieved in concert with minimum system costs.

4. CURRENT STATE OF ART: Software cost is greater than hardware cost. Techniques have been proposed but not demonstrated. HOL computers may decrease software development; their architectures have been studied. HAS BEEN CARRIED TO LEVEL 7

5 DESCRIPTION OF TECHNOLOGY: Onboard software programs are required for control and monitoring of automatic functions performed by onboard computers. Onboard functions can be implemented either by computer software or dedicated hardware. Computer software is more flexible and can be changed more easily than dedicated hardware to adapt to new or changed requirements. However, debugging and verifying software can be very expensive. New techniques to reduce software development cost are necessary to get maximum useful data from experiment operation in space.

Software techniques must be developed for manned intervention into the automatic software controlled computer processes by interactive graphics type terminals on-board and/or on the ground. This will allow the operator to alter the automatic process or to obtain additional data not made available to the operator on a routine basis.

The development of optimum software control strategies and control factors for executing planetary terminal rendezvous and docking maneuvers is a complex procedure that involves a great deal of trial, iteration and refinement. Methods for optimizing the initial closing ΔV maneuver, the subsequent range rate and line of sight control, and the docking algorithm must be analyzed and then demonstrated in a computer and by physical simulations.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. The advanced technology is required to reduce the cost of software development including documentation by approximately a factor of four as per above objective.

b. All payloads will probably use a computer so all are likely to benefit PL-01-A, Mars Surface Sample Return, will benefit from the planetary rendezvous and docking technology advancement.

c. Lower cost software development will allow more of the money available for the payload to be spent on hardware to provide more and/or better data for the experimenter.

d. Some software techniques can be demonstrated by analysis, others by being applied to a current software development for another program.

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TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C19.1

1 TECHNOLOGY REQUIREMENT(TITLE, Onboard Software, for PAGE 2 OF 3
payload monitoring control, checkout, redundancy management and rendezvous and docking.

7 TECHNOLOGY OPTIONS: The following technology options should be considered to reduce software development cost:

a. Establish standardized software management guidelines and rules for the utilization of the "top down" and "structured programming" approaches to software development including such concepts as librarian and chief programmer concepts. Develop standardized approach to requirements and specifications. Develop automated documentation generation techniques. Develop standardized utility software for both ground and onboard use.
b. Develop a generalized checkout philosophy utilizing an optimum combination of software and hardware performance monitoring such as test pattern generation programs.
c. Develop redundancy management techniques utilizing cost effective combinations of autonomous onboard control and ground control.
d. Utilize HOL to reduce software cost. The concept of a HOL machine should be considered.
e. Develop architectural and data base designs that allow ease in implementing application software.
f. Develop microcoded operators/operands at both algorithm and software system level.

8. TECHNICAL PROBLEMS:

Early and firm specification of the functional and reliability requirements, load and throughput or response time requirements, plus the resources (CPU, memory, peripherals and special purpose hardware) that will be available to the software program.

Determination of tradeoffs between flexibility of a larger processor and the use of independent firmware modules.

9. POTENTIAL ALTERNATIVES:

a. Do data processing on ground with man assistance.
b. Reduce amount of data collected and/or processed.
c. Reuse software previously developed for other programs.

10 PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP W-75 (656-12-01), Systems Analysis, Concepts and Modeling for Optimum Data Flow, NASA/MSFC, G. F. McDonough, (205) 453-3723.

RTOP W74-70358 (502-23-32), Automated Data Handling Techniques and Components, GSFC, D. H. Schaefer, (301) 982-5184.

Feasibility Study of Unmanned Rendezvous and Docking in Mars Orbit, NAS 7-100, June '74.

EXPECTED UNPERTURBED LEVEL 7

11 RELATED TECHNOLOGY REQUIREMENTS:

a. Low cost, low weight, low power computer memories.
b. Fast, low weight computers.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C19.1

1. TECHNOLOGY REQUIREMENT (TITLE): Onboard Software, for payload monitoring control, checkout, redundancy management and rendezvous and docking. PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90			
TECHNOLOGY																			
1. Parametric Analysis																			
2. Selection of Techniques																			
3. Demonstration Plans																			
4. Perform Demonstrations																			
APPLICATION																			
1. Design (Phase C)																			
2. Devel./Fab. (Phase D)										T1									
3. Operations																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
TECHNOLOGY NEED DATE		T															
NUMBER OF LAUNCHES										T1 2							1364

14. REFERENCES:

a. Summarized NASA Payload Descriptions, Sortie Payloads, Level A, July 1974, NASA/MSFC.

b. Summarized NASA Payload Descriptions, Automated Payloads, Level A, July 1974, NASA/MSFC.

Legend:

T: Technology
—: Automated Operations
T1: PL-01-A, Mars Surface Sample Return

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C19.2

1. TECHNOLOGY REQUIREMENT (TITLE): Software for GN&C; to support high accuracy earth and planetary observation experiment pointing PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Software

3. OBJECTIVE/ADVANCEMENT REQUIRED: An accuracy of 5m is required for earth observation mapping experiments

4. CURRENT STATE OF ART: Accuracy in the range of 30-100m is quite reasonable. The AF Global Positioning System is in development.

HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY: The altitude and the required ground resolution determine the accuracy with which the orbit elements and attitude variables must be known. The error sources do not have comparable effects on image quality. An error in altitude effects scaling whereas along-track and cross-track errors in orbit elements affect positioning. An angle error about the local vertical does not have the same kind of effect as angular errors about the other two axes. Moreover, some of these error sources may not be clearly distinguishable. For example, an angular error about the velocity vector has effects somewhat similar to a cross-track orbit error. Therefore, the overall picture quality depends heavily on how these errors are estimated and eliminated.

The highly accurate navigation required probably cannot be accomplished by an autonomous on-board inertial reference system. Some form of landmark tracking combined with star tracker, horizon sensor, and TDRS tracking will be used. This multisensor correlation along with pattern recognition for landmark tracking will involve the development of new software techniques beyond those used for the Orbiter vehicle.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Accurate navigation is required to allow registration accuracy to 0.1 picture elements (pixels). New software techniques can increase the navigation accuracy utilizing the outputs of advanced GN&C equipment.
b. Benefitting payloads are: EO-08-A, Earth Observatory Satellite, EO-61-A, Earth Resources Survey Operational Sat., OP-02-S, Multifrequency Radar Land Imagery, OP-05-S, Multispectral Scanning Imagery.
c. Better picture quality will be possible.
d. Technology objectives can be demonstrated by flying a model of the instruments and the corresponding software on a Shuttle sortie flight.
Initial demonstration test will be performed in the laboratory.

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TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C19.2

1. TECHNOLOGY REQUIREMENT(TITLE): Software for GN&C: to support high accuracy earth and planetary observation experiment pointing

7. TECHNOLOGY OPTIONS:

Accurate navigation (position determination) cannot be achieved by software alone. High accuracy gyros, accelerometers, star trackers and horizon sensors are also required. Proper data processing of the outputs of these components can enhance the navigation accuracy.

Options include various combinations of the use of sensors such as inertial platform (gimballed or strapdown), star tracker, horizon sensor, landmark tracking, TDRS, ground tracking update. Passive ranging techniques with interferometric landmark tracking may closely satisfy requirements. Use Kalman filtering to combine data from various sensors to achieve improved accuracy.

8. TECHNICAL PROBLEMS:

a. Development of accurate hardware sensors.
b. High speed computational capacity.
c. State determination using landmarks in image data (e.g., cataloging, landmark identification, etc.).
d. State determination using integrated multisensor data.

9. POTENTIAL ALTERNATIVES:

a. Ground tracking for spacecraft position determination.
b. TDRSS tracking for spacecraft position determination.
c. Use of the Tri-Service Global Positioning System (NAVSTAR).
d. Use of space sextant with a measurement accuracy of one arc-sec or less.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. W74-70709 (310-10-22), Mission Support Computing Systems and Techniques, GSFC, D. S. Woolston, (301) 982-5571.
b. W74-70380 (502-33-41), Guidance and Navigation for Unmanned Planetary Vehicles, JPL, Robert V. Powell, (213) 354-6586.
c. High Altitude Navigation Technology, SAMSO/DYAG, 1st Lt. Gary Greenleaf, (213) 643-1414.

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

Development of accurate navigation sensors.

Development of accurate attitude control and pointing control.

Development of clock accurate to 0.001 seconds.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. C19.2

1. TECHNOLOGY REQUIREMENT (TITLE): Software for GN&C; to support high accuracy earth and planetary observation experiment pointing — PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Options & Param. Analy.	—																		
2. Design Model	—																		
3. Build Model	—	—																	
4. Test Model		—			—	—	—												
APPLICATION																			
1. Design (Phas C)		—	—																
2. Devel./Fab. (Phase D)			—	—	—														
3. Operations				T1 T2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
13. USAGE SCHEDULE:				T3 T4		●● ●●	●● ●●	●● ●●	●● ●●	● ●	● ●	● ●	●● ●●	●● ●●	●● ●●	● ●	● ●		
TECHNOLOGY NEED DATE		T																	Total
NUMBER OF LAUNCHES					2	6	6	6	5	4	3	4	6	5	6	3	4		60

14. REFERENCES:

a. Summarized NASA Payload Descriptions, Automated Payloads, Level A Data, July 1974, NASA/MSFC.

b. Summarized NASA Payload Descriptions, Sortie Payloads, Level A Data, July 1974, NASA/MSFC.

c. Advanced Scanners and Imaging Systems for Earth Observations, NASA SP-335, 1973, pp. 459-60.

Legend:

T	Technology
●	Sortie Operations
—	Automated Operations
T1	EO-08-A, Earth Observatory Satellite
T2	EO-61-A, Earth Resources Survey Operational Sat.
T3	OP-02-S, Multifrequency Radar Land Imagery
T4	OP-05-S, Multispectral Scanning Imagery

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

Revised 12/2/74

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. C19.3

1. TECHNOLOGY REQUIREMENT (TITLE): Software for Attitude Control; Accurate Pointing of Experiment Sensors — PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Software

3. OBJECTIVE/ADVANCEMENT REQUIRED: Attitude sensing accuracy of ±0.0001 to 0.001 degree and tracking error signal of 0.1 to 3.0 arc sec are required to allow accurate comparison of picture elements data from different views of the same arcs on the earth's surface.

4. CURRENT STATE OF ART: Military METSAT is capable of ±0.01 degree sensing accuracy using strapped down inertial measurement unit and star sensors. 3 arc sec is achieved currently on the NASA/Ames C-141. Also OAO spacecraft are in operation.

HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY: The earth observing sensor carried as a payload on a platform naturally imposes certain requirements on the nature and quality of platform motions, and the knowledge of such motions. To accurately locate a desired target on the ground within the sensor field of view, it must be possible to orient a platform-to-ground line-of-sight vector to adequate accuracies. The variables defining the platform trajectory (or orbit) and orientation (or attitude) must be known accurately to allow precise identification of the intersection point of the line-of-sight vector with earth's aurface. Each of these variables has a separate accuracy requirement.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Attitude sensing accuracy of ±0.0001 to 0.001 degree and tracking error signal of 0.1 to 0.3 arc sec are required.

b. The benefitting payload is EO-61-A, Earth Resources Survey Operational Sat. for the sensing accuracy of ±0.0001 to 0.001 degree. Most of the Astronomy and High Energy Astrophysics payloads will benefit from the requirement for tracking error signal of 0.1 to 0.3 arc sec.

c. Earth sensing data will be able to be geometrically corrected to about one tenth of an IFOV. This will be critical in operational earth resources and cartographic missions requiring precise location of features on the ground.

d. The technology can be demonstrated by flying a model of the hardware and software in an orbiter mission.

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TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C19.3

1. TECHNOLOGY REQUIREMENT(TITLE): Software for Attitude Control; PAGE 2 OF 3

Accurate Pointing of Experiment Sensors

7. TECHNOLOGY OPTIONS:

Techniques that extend the use of Kalman filtering, coordinate conversions, and closed loop actuator control beyond the current state-of-the-art.

Software for new computer architectures for high rate and precision computations.

Use of a space sextant, an inertial platform and a Kalman filter attitude determination program.

8. TECHNICAL PROBLEMS: Studies and design efforts by Draper Laboratories (1972), TRW and Honeywell, indicate that attitude accuracy of 18 microradians (0.001 degree) one sigma, or better, without using payload sensor data, may be achievable within the next several years if adequate efforts are made. MMC believes attitude accuracies of 0.0001 degree (one sigma) may be achievable by 1979 using a space sextant.

There is no insurmountable technological barrier in achieving post flight attitude determination accuracies below 10 microradians for the several minutes of time an ERTS-type satellite takes to pass over the continental United States.

9. POTENTIAL ALTERNATIVES:

a. Use post-flight smoothing and apply attitude and orbit corrections during data processing to improve image quality.
b. Use ground based precision orbit and attitude determination systems with a loosely controlled low jitter platform.
c. Use self contained motion or jitter compensation hardware and software to improve image quality.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. W74-70354 (502-23-43), Advanced Components for Precision Control Systems, GSFC, H. E. Evans, (301)-982-5194.
b. W74-70458 (175-31-41), Spacecraft Subsystems Analysis and Design, GSFC, John Flaherty, (301)-982-6862.

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Development of precision attitude sensor.
b. Low jitter electromechanical scanner.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C19.3

TECHNOLOGY REQUIREMENT (TITLE): Software for Attitude Control; Accurate Pointing of Experiment Sensors PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Parametric Analysis																			
2. Design Software																			
3. Integrate w/Hardware																			
4. Test Model																			
APPLICATION																			
1. Design (Phase C)																			
2. Devel./Fab. (Phase D)																			
3. Operations				T1															
				T															
13. USAGE SCHEDULE:				T															
TECHNOLOGY NEED DATE				T															Total
NUMBER OF LAUNCHES		T1 T2 T3			1 12	1 17 2	1 21 1	1 20 4	1 21 2	1 23 3	1 24 1	1 25 5	1 23 2	1 24 2	1 22 1	1 22 2	1 24 3		309

14. REFERENCES:

a. Summarized NASA Payload Descriptions, Automated Payloads, Level A Data, July 1974, NASA/MSFC, p. 98.

b. Advanced Scanners and Imaging Systems for Earth Observations, NASA SP-335, pp. 462-65.

c. Statement of Work, Spacecraft Adaptable Software Concept Study, NASA/LaRC, March 29, 1974, RFP 1-15-4529.

Legend:

T Technology
T1 EO-61-A, Earth Resources Survey Operational Sat.
T2 Astronomy Payloads
T3 High Energy Astrophysics payloads

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-19.4

1. TECHNOLOGY REQUIREMENT (TITLE): SOFTWARE, for experiment operation accurate control, monitoring, quality control, high data rate processing. PAGE 1 OF 6

2. TECHNOLOGY CATEGORY: Software/Computer Configuration

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop technology of software and hardware configurations to provide maximum data processing support for real time experiment operation.

4. CURRENT STATE OF ART: OAO operates five experiment functions concurrently. The C-141 is flying with up to 5 computers to operate one primary and two secondary experiments HAS BEEN CARRIED TO LEVEL 7

5. DESCRIPTION OF TECHNOLOGY

Payloads require data processing support for automation of functions that the experiment operator cannot directly accomplish. The amount of useful data obtained during a mission is directly related to the efficiency with which the experiments are operated. Data processing automation is required to allow up to 85 experiments to be operated concurrently and monitored by one or two observers. Software and computer configurations to provide the necessary data processing support must be developed at a reasonable cost.

P/L REQUIREMENTS BASED ON: [X] PRE-A, [ ] A, [ ] B, [ ] C/D

6. RATIONALE AND ANALYSIS:

a. Many basic software/hardware configurations exist that provide data processing support to automate equipment operation. Two examples are process control computer systems and avionics computer systems. These existing systems are not capable of handling the complex data processing task required to automate the operation of the experiment payloads such as those that require pointing as many as 6 sensors in different directions concurrently, fast fourier transform with 10^6 spectral elements, determining and displaying contours from image data, software to support Livermore AEC type display with color resolution equivalent to 4096 gray levels (false color technique) 5000 × 5000 point resolution image (8 bits per point) superimposition to improve dynamic range and reduce data rate to ground. Table 1 shows some typical payload data processing requirements. (cont'd on page 2)

1. TECHNOLOGY REQUIREMENT (TITLE): SOFTWARE, for experiment operation accurate control, monitoring, quality control, high data rate processing.

6. RATIONALE AND ANALYSIS (CONTINUED)

b. All payloads will benefit, in particular AS-31-S, combined AS-01, -03, -04, -05-S, and SO-01-S, dedicated solar sortie mission (DSSM).

c. Experiment operator must have very effective data processing support to monitor several concurrently operating experiments for proper operation and to make necessary adjustments to experiment operation based on the quick look data.

d. The level of technological maturity is the laboratory simulation of software techniques being developed. This simulation should demonstrate that an operator can monitor and control a full set of experiments concurrently. It is also necessary to demonstrate that data processing hardware techniques are available to implement the software techniques that have been developed. It is important that hardware size, weight and electrical power requirements are compatible with the Orbiter PSS and pallet mounting locations.

TO BE CARRIED TO LEVEL 8

7. TECHNOLOGY OPTIONS:

The following items need to be traded for application to providing the required software/computer configurations:

1. Use a voice recognition processor to execute commands spoken by the airborne experiment controller.
2. Develop a general purpose, real time multiprogramming executive and integrate it with a microprogrammable processor to reduce executive overhead and achieve flexibility.
3. Demonstrate software executive control of a configuration of CPUs in a multiprocessor configuration with a flexible dedication of memory in blocks to individual CPUs with CPUs dedicated to functional sets of sensors provided by a particular experimenter. Subgroups of CPUs should operate as a multiprocessor or perform parallel processing for sensor data channels. Software and hardware should be dynamically reconfigurable for CPU or memory failures and adapt to processing requirement changes.
4. Identify and develop generalized utility programs of general use to a large number of payloads such as data formatting, data display.
5. Establish efficient techniques for verifying and validating computer programs by use of a software generator system and interpretive language techniques to assure that new software or new command sequences will not interfere with existing software operation.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-19.4

1. TECHNOLOGY REQUIREMENT (TITLE): Software, for experiment operation accurate control, monitoring, quality of control, high data rate processing.

7. TECHNOLOGY OPTIONS (Continued)

Develop proof of correctness techniques for checking out key elements of software such as executive.

6. Develop software for an RF or light multiplexed data bus operating at 100 mhz (for example) with 20 or 30 separate 1 or 2 Mbps digital buses for separate functions or sensors as required to operate either under computer software control or under sensor control.

7. Select and/or develop standard data compression techniques to be applied to sensor data to be recorded or transmitted to ground. Demonstrate the separation of information from data at the sensor to reduce data rates. The scientists must be assured that no useful data is lost.

8. Develop hardware/software techniques for accurate time correlation of experiment data.

9. Develop methods of monitoring and displaying sensor data efficiently to determine if real time adjustments need to be made in the experiment operation.

10. Develop techniques for a real time virtual memory implementation.

11. Develop a set of standard, flexible software modules to meet all payload requirements by standardizing hardware interface with computer.

12. Develop computer input/output techniques to handle high data rates (up to 700 Mbps total for SO-01-S) by use of dedicated data processors for each sensor to reduce data rates. High data rates exist only in each experiment and each individual sensor.

13. Develop a standardized central stratum for use with those payloads using distributed computers to eliminate control and allow another computer to assume the primary functions of a failed computer.

14. Develop techniques to reduce overhead during software execution (more efficient executives).

15. On-board image processing for conical-scan conversion. (Ref. f., p. 506).

16. Develop micro-processor capability to handle man/machine conversions of data for use with operator control displays.

The critical parameter is the degree of payload automation required to allow one observer to monitor multiple experiments operating concurrently with simple low cost software and compact, low weight, inexpensive hardware.

DEFINITION OF TECHNOLOGY REQUIREMENTS NO. C-19.4

1. TECHNOLOGY REQUIREMENT (TITLE): SOFTWARE, for experiment operation accurate control, monitoring, quality control, high data rate processing.

8. TECHNICAL PROBLEMS:

1. Early determination of detailed data processing requirements from experimenters. Degree of automation allowed by experiments must be defined early.
2. Reduction of software complexity.
3. Real time 10^6 point fast fourier transformation.

9. POTENTIAL ALTERNATIVES:

1. Extensive use of ground facilities.
2. Limit the number of experiments carried on each mission.
3. Reduce the objectives of the experiments.
4. Increase the time duration of each mission.
5. Accumulate large amounts of raw data on film or tape to be reduced for users after the mission.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT

1. SUMC, AADC, MSC, etc. LSI computer developments will increase hardware capability.
2. Bubble, CCD, and DOT mass memory and recorder developments will greatly expand storage capacity.
3. No directly applicable software or special purpose hardware advancement expected.
4. RTOP W74-70459 (175-31-42), Spacecraft Data Processing, NASA/GSFC, Marvin Maxwell, (301) 982-4036.
5. RTOP W-75 (656-11-04), User Technology, NASA/MSFC, G. F. McDonough, (205) 453-3723.
6. RTOP W-75 (656-12-01), Systems Analysis, Concepts and Modeling for Optimum Data Flow, NASA/MSFC, G. F. McDonough, (205) 453-3723.

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Accurate GN&C pointing up to 0.01°

b. Support for basic vehicle operation.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-19.4

11. TECHNOLOGY REQUIREMENT (TITLE): SOFTWARE, for experiment operation accurate control, monitoring, quality control, high data rate processing

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Parametric Analysis																			
2. Design Software																			
3. Integrate W/Hardware																			
4. Test Model																			
APPLICATION																			
1. Design (Phase C)																			
2. Development/Fabrication (Phase D)																			
3. Operations					T1 T2 T3 T4														

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				T														
NUMBER OF LAUNCHES						T1 T2 T3 T4	T1 T2	T1 T2	T1 2T2	T1 2T2	2T1 2T2	2T1 2T2	2T1 2T2	2T1 2T2	2T1 2T2	2T1 2T2	2T1 3T[illegible]	1364

14. REFERENCES

a. Aspen International Conference on Fourier Spectroscopy, 1970, AFCRL. pp. 83-119.

b. Summarized NASA Payload Descriptions, Sortie Payloads, July 1974 NASA/MSFC.

c. Spacelab Sortie Payload Software Sizing Analysis, Feb. 1974, IBM.

d. Summarized NASA Payload Descriptions, Automated Payloads, July 1974, NASA/MSFC.

e. Statement of Work, Spacecraft Adaptable Software Concept Study, NASA/LaRC. March 29, 1974, RFP 1-15-4529.

f. Advanced Scanners and Imaging Systems for Earth Observations, NASA SP-335, 1973 p 506-27.

LEGEND

(T1) = AS-31-S, Combined AS-01,-03,-04,-05-S

(T2) = SO-01-S, Dedicated Solar Sortie Mission (DSSM)

(T3) = Other sortie flights.

(T4) = Automated payload flights.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED
2. THEORY FORMULATED TO DESCRIBE PHENOMENA
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G. MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

1. TECHNOLOGY REQUIREMENT (TITLE): SOFTWARE, for experiment operation accurate control, monitoring, quality control, high data rate processing.

Table 1. DATA PROCESSING REQUIREMENTS VS PAYLOADS

Payload		Number of Simultaneously Operating Sensors/ Data Channels	Output Data Rate BPS	Control/Display							On Board Data Processing						
														Rapid Access Memory		Bulk Memory	
Ref. No.	Name			Observers/ Shift	Number of Keyboards	Number of Indicator/Switches (3)	% of C/O Automated	Number of Interactive Displays	Display Area m^2 (ft^2)	Number of Simultaneous Functions	Number of Channels/Routines	Computations per Second	Word Length Bits	Number of Words	Access Time (μsecs) *	Number of Words	Access Time (μsecs)
AS-22-S	Combined Astronomy Sortie	8 exp(1) 6 pt.	2.6×10^4	1	1	68	90	2	0.78 (8.38)	9	9	50K	32	8K	5	125K	50
SO-31-S	Dedicated Solar Sortie Mission	85 exp 12 to 15 pt	1.3×10^7	2	2	340	60	4	1.91 (20.5)	97	97	200K	32	32K	2.5	500K	25
AP-05-S	Atmospheric & Space Plasma Physics	22(2) 22 pt	10^6	2 to 3	2	352	60	4	1.12 (12) to 4.46 (48)	44	44	86K	16	32K	1	30M	1000
EO-01-S	Earth Resources Survey Facility (ESRO)	11 exp 14 pt	6.25×10^7	1	1	44	60	1	$2m^2$ (21.6) to 4 (43.2)	25	25	100K	32	56K	1	608K	10^4
SP-14-S	Space Processing Applications	4 exp	1.4×10^4	1 One Shift Only	1	18	30	1	1.116	4	4	(10K)	(16)	(8K)	(50)	None	—
LS-09-S	Life Sciences Shuttle Lab + Research Center	24 exp	3.4×10^4	3 One Shift Only	2	200	30	1	0.56 (6)	24-100	24-100	10K	16	32K	1	10M	15×10^6

(1) 9 channels standby
(2) 66 channels standby

exp = Experiment output channels
pt = Pointing & stabilization channels
* = Access time to one cycle of input/output data

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE 19.5

1. TECHNOLOGY REQUIREMENT (TITLE): On-board processing of Mission Data for Payload Experiments/Operations. PAGE 1 OF 5

2. TECHNOLOGY CATEGORY: Software/Systems

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop advanced software and system techniques for on-board and ground processing of remote sensing data.

4. CURRENT STATE OF ART: Limited on-board processing is planned for automated spacecraft in 1978-1980 time frame.

HAS BEEN CARRIED TO LEVEL 6

5. DESCRIPTION OF TECHNOLOGY

Technological advances are needed in software, on-board processors, and the techniques for utilizing these most effectively to handle the increasing complexity of multi-sensor, multi-disciplinary payloads that will service a large number and broad variety of users. Current techniques for on-board and ground processing of earth-sensing data are based on limited knowledge of user requirements, and are tailored to individual sensors rather than observational systems.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS: A.

The processing of mission data requires a large portion of the overall cost of orbital remote sensing systems. The processes encompass all the functions required between the sensor's output and the input to the users. The system required for their implementation must provide optimum allocation of those functions that are more efficiently accomplished on-board and those that should be performed in ground based facilities. Candidate functions for on-board processing include geometric, radiometric and dynamic response corrections, data compaction, and information extractive processes. In order to realize significant savings in design, procurement and operation of these systems, the advances in software, on-board processors and implementation techniques must be based on satisfying current and projected user needs. These needs vary according to the type of investigation being performed, from the gathering of data using very new (unproven) sensor concepts, to repetitive operational surveys of national or global scope. Thus, the first input to the technology program should be a statement of specific user requirements in remote sensing disciplines, representative of the spectrum of current and future users such as that prepared by the TERSSE Study for OA/ERPO. Having established the baseline, the following steps will be required:

(continued on page 2)

TO BE CARRIED TO LEVEL 8

1. TECHNOLOGY REQUIREMENT (TITLE): On-board processing of Mission Data for Payload Experiments/Operations.

(C Continued)

a) Determination of the characteristics of the data processes needed to do data correction and extraction. Included here should be not only data transformation, but also consideration of the data transmission links and attendant data compression requirements.

b) Commonality analyses to permit the grouping of user requirement categories and attendant characteristics according to similarities in implementation needs.

c) Assessment of current and projected state-of-the-art in software, processors, memory devices, computer attitude determination systems data links, etc. as they relate to the user requirements, characteristics and groupings in a and b above.

d) Determination of cost-effective implementation approach applicable to specific cases in each user requirement category. The primary criteria will be cost, and will consider centralized and distributed networks of ground-based facilities as well as on-board processing equipment.

e) Technology advances will be effected to permit the implementation of the approaches in d above, within the time constraints of the specific payloads affected.

B.

The payloads that will benefit from this program are automated and sortie P/L's in Earth Observation, Earth and Ocean Physics, Atmospheric and Space Physics, Astronomy, High Energy Astrophysics and Solar Physics.

C.

Using cost as a primary criterion, this advancement potentially will aid in realizing a significant portion of the future resources allocated to space payloads (including not only NASA's but also NOAA, DOD, DOI, DoA's etc.).

D.

The level of technological maturity required is the analysis of at least one representative payload in each user requirement category. Probably extensive use of on-board processing will not be accepted by the users prior to demonstration on a spacecraft.

DEFINITION OF TECHNOLOGY REQUIREMENT NO GE 19.5

1. TECHNOLOGY REQUIREMENT(TITLE): On-board processing of Mission Data for Payload Experiments/Operations

7. TECHNOLOGY OPTIONS:

The technology advance encompasses the following parameters:

a) Time constraints between data acquisition and data dissemination to the user.
b) Desired format(s) for presentation of data to the user
c) Cost-including development and recurring cost of software and hardware necessary to implement approaches.
d) Quality (accuracy, resolution, linearity) of data associated with each approach (e.g. real-time vs. non real-time correlation)
e) Impact of the approach upon the required communication link (e.g. use of HADAMARD transformation may improve the manner in which noise is manifested in the transmitted signal).

(continued on page 4)

8. TECHNICAL PROBLEMS:

a. Assessment of current user needs and projection of future needs.

b. Projection of future technology advances that will impact the trade-off analyses.

c. Accurate definition of the end-to-end data flow needs of the system.

9. POTENTIAL ALTERNATIVES:

An alternative to the development of this methodology is to perform detailed trade-off analyses or each individual payload that is flown. In some payloads the similarities would be evident enough to permit the use of the results of one payload to apply to another.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

The following RTOP's apply to individual aspects of data processing in remote sensing applications:

177-23-61	177-31-41	177-32-71	177-42-41	177-42-82
177-25-51	177-32-11	177-42-21	177-42-81	177-42-81
177-26-41	177-32-61			

EXPECTED UNPERTURBED LEVEL 6

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Sensor development trends and projections
b. Advancements in software designs
c. Advancements in data processors
d. Pointing and tracking systems

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE 19.5

1. TECHNOLOGY REQUIREMENT (TITLE): On-board processing of Mission Data for Payload Experiments/Operations. PAGE 4 OF 5

7. (Continued)

f) Grow h in technology capability in software and hardware (e.g. use of Tukey-Cooley algorithms to reduce computation time requirements; deve opment of a chip for performing Fourier transforms in multi-element arrays.)

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OF POOR QUALITY

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE 19.5

1 TECHNOLOGY REQUIREMENT (TITLE): On-board processing of Mission Data for Payload Experiments/Operations. PAGE 5 OF 5

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. USER SURVEY																			
2. REQUIREMENTS DEFINITION																			
3. S.O.A. ASSESSMENT																			
4. TRADEOFFS																			
5. DEVELOPMENTS																			
APPLICATION																			
1. Design (Ph. C) N/A																			
2. Devl/Fab (Ph. D) N/A																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				△														
NUMBER OF LAUNCHES *					19	14	17	14	12	11	16	20	19	21	17	23	18	221

14 REFERENCES:

Earth Observation Satellite System Definition Study Report No. 3: Design Cost Trade-off Studies and Recommendations.

Total Earth Resources System for the Shuttle Era Final Report, Vol. 3.

* Based on automated P/L launches in the applicable disciplines.

15. LEVEL OF STATE OF ART

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6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
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9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE 19.6

1. TECHNOLOGY REQUIREMENT (TITLE): Data Retrieval & Ground-Based Transformation and Distribution PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Software/Systems

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop software and systems for transforming data into the user's frame of reference and permitting his rapid remote access to it.

4. CURRENT STATE OF ART: AFOS distribution system permits rapid access; GE image 100 permits rapid processing; transformation/gridding processors are not yet developed.

HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

Future Earth observations systems will produce data for a multitude of users who are performing various tasks and who are geographically distributed. The users all have individual frames of reference and information extraction needs. Systems and software required which can access Earth Observations data banks, transform the coordinates of the data into user-determined systems, and permit the user to interactively process the data for his own needs via low-cost remote terminals. The systems will encompass large mass storage, special purpose processors, telecommunications links, and low-cost interactive remote terminals.

Current Earth Observations technology has progressed only to the point of preprocessing. A few first-generation systems exist for rapid extractive processing but no distributed time-shared system has been concieved.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

A. The data retrieval and transformation/distribution system will require several technological advances in the area of processors, time-sharing strategies, telecommunications, and remote terminals. Low cost is of utmost importance because of the ultimate large number of such systems to be implemented. The planned U.S. Domestic Communications Network is an enabling technology, High-speed digital equipment and large memory-storage technologies are potential sources for solutions.

B. Payloads in Earth Observations, Earth and Ocean Physics, and Atmospheric Physics will benefit from this technology advancement.

C. This advancement would be useful in realizing significant savings in the resources allocated to payloads.

D. The technology program will require the demonstration of the system through modeling techniques, using a representative spectrum of user requirements.

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TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE 19.6

1. TECHNOLOGY REQUIREMENT(TITLE): Data Retrieval & Ground-Based Transformation and Distribution PAGE 2 OF 3

TECHNOLOGY OPTIONS:

Technology options exist at each stage of the process. Retrieval can be accomplished either manually or by machine. The transformation to the user's coordinates must be done at high speed but with great flexibility, leading to a trade between special purpose and general purpose machines. The distribution option involves a bandwidth versus terminal cost trade.

8. TECHNICAL PROBLEMS:

Data compression: high-speed digital logic that is flexible; standardization of user terminals, formats, and procedures.

9. POTENTIAL ALTERNATIVES:

Totally centralized processing and/or mail distribution for analysis on user computers where they exist.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

None known.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

Sensor design, telecommunications development, onboard processing large data base development, applications development (by OA)

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. GE 19.6

1. TECHNOLOGY REQUIREMENT (TITLE): Data Retrieval, Transformation and Distribution

PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. TRANSFORMATION SYSTEM	—																		
2. TERMINAL SYSTEM	—	—																	
3. RETRIEVAL SYSTEM		—																	
4. MANAGEMENT SYSTEM	—	—																	
5.																			
APPLICATION																			
1. Design (Ph. C)		—	—																
2. Devl/Fab (Ph. D)			—	—															
3. Operations				—	—	—	—	—	—	—	—	—	—	—	—	—	—		
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				△														
NUMBER OF LAUNCHES						(TBD)												

14. REFERENCES:

1. Total Earth Resources System for the Shuttle Era, Final Report, Volumes 1 & 3.

2. Office of Applications Earth Resources Program Summary, NASA S 74 36275

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
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10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

8
REFERENCES

The applicable references and data sources are listed in Paragraph 14 "REFERENCES" of each "Definition of Technology Requirement" item in Section 7 of this report.

APPENDIX A

PERSONNEL CONTACTED

CONTENTS

APPENDIX A

NASA AND JPL CONTACTS

A.1 NASA/OAST PAYLOAD TECHNOLOGY PANEL AND DIRECTLY SUPPORTING PERSONNEL

NASA Headquarters
Washington, D.C. 20546
RX/S. Sadin
SL/R. Tarver
RS/W. Hayes
RS/E. Gabris
REM/H. Anderton
MK/G. Esenwein
RC/F. Demeritte
RC/A. Henderson
RX/G. Kayten
SG/R. Chandler

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Greenbelt, MD 20771
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Langley Research Center
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Hampton, VA 23365
412/R. Osborne

George C. Marshall Space Flight Center
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Lyndon B. Johnson Space Center
Houston, Texas 77058
CB/J. Allen

Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91103
Frank T. Barath/M.S. 186-118

Ames Research Center
Moffett Field, CA 94035
202-5/A. Worden, Panel Chairman
202-9/L. Alton

Lewis Research Center
21000 Brookpark Rd.
Cleveland, Ohio 44135
5401/E. Otto

John F. Kennedy Space Center
Kennedy Space Center, Florida 32899
SO-B/J. Clark
DD-SED-4/W. Boggs

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Los Angeles, CA 90009

APPENDIX A

PERSONNEL CONTACTED

A.2 NASA HEADQUARTERS, Washington, D.C. 20546

Name	Discipline/Category
Dr. Jeffrey D. Rosendhal	Astronomy
Dr. Albert Opp	Astrophysics
Dr. Adrienne Timothy	Solar Physics
Fred Berko	Atmospheric and Space Physics
Pitt G. Thome	Earth Observations
Dr. Joseph W. Siry (GSFC)	Earth & Ocean Physics
Dr. James H. Bredt	Space Processing
Dr. Rufus R. Hessberg	Life Sciences
Robert W. Dunning	Life Sciences
Edward Gabris	Space Technology
Paul Tarver	Planetary
Samuel W. Fordyce	Communication/Navigation
C. E. Pontius	Communication/Navigation
Franklin D. Martin	Lunar
Floyd L. Roberson	Lunar
Jules Lehman	Sensors
George C. Deutch	Structures/Mechanical & Materials
Norman J. Mayer	Structures/Mechanical & Materials
James Gangler	Structures/Mechanical & Materials
Bernard G. Achhammer	Environmental Control
Dr. Joseph G. Lundholm, Jr.	Radiation Protection/Hardening
Dr. Peter Kurzhals	GN & C/Attitude Control
Clarence E. Catoe	TT&C/Data
Dr. Bernard Rubin	Sensors, Systems and Instrument Electronics
Ernst M. Cohn	Electrical Power
James Lazar	Propulsion
Frank W. Stephenson, Jr.	Propulsion

APPENDIX A

PERSONNEL CONTACTED

A.3 GODDARD SPACE FLIGHT CENTER, Greenbelt, Maryland 20771

Name	Item No.	Subject/Category
Peter Argentiero	18.5	Gravity Analog/Digital Filtering
Dr. S. Auer	5.3	Solids Analysis - Comet Tail
Charles Capps	19.1 thru 19.4	Software
Ed Chin	1.4	UV - IR Telescope, Large Optics
	2.7	UV Echelle Spectrograph
	8.-	Contamination
Jerome Eckerman	1.9	Ratio-Large Microwave Antenna Arrays
	4.3	Synthetic Aperture Radar
Carl E. Fichtel/	1.1	Gamma-Ray Survey Instrument, Large
R. Hartman	2.1	Cosmic Ray Spatial Detector
	9.3	Cosmic Ray/Gamma Ray Protective Shell
	18.1	High Energy Pulse Measurement and Correlation Detection
Dr. M. W. Fitzmaurice	3.1	VIS & IR Laser
	4.1	IR LIDAR System
Arthur J. Fuchs	19.1 thru 19.4	Software
I. Larry Goldberg	2.16	IR Pyroelectric Detector, Uncooled
Henry Hoffman	15.5	Earth Resource - Star Sensor, Strapped Down, Advanced Gyro
Stephen S. Holt	1.2	X-Ray Telescope
	2.2	X-Ray Transmission Grating
	2.3-1	X-Ray Maximum Sensitivity Detector
	2.3-2	X-Ray Polarimeter
	2.4 & 2.5	X-Ray Proportional Counter, Position Sensing
	2.6	X-Ray Converter/Intensifier
	9.6	X-Ray Instrument Mount/Selector
Dr. Robert Hunter	14.1	Planetary-Thruster, Mercury Ion
	14.2	Sta. Keeping-Thruster, Cesium Bombardment
Seymour Kant	2.8 thru 2.11	VIS - IR Mapper
	6.1	Gradiometer Accelerometer
Robert E. Kidwell	2.26	Relativity - Precession Gyroscope
	10.1	IR Chamber/Selector
	12.1	Super-conduction - Cryostat Dewar, He II
	12.2	Long Duration IR Missions - Helium Reliquification

APPENDIX A

PERSONNEL CONTACTED

A.3 GODDARD SPACE FLIGHT CENTER, Greenbelt, Maryland 20771 (Continued)

Name	Item No.	Subject/Category
Marvin S. Maxwell	2.8 thru 2.10	VIS - IR Mapper
	19.4	Software for Experimental Control
John McElroy	3.1	VIS & IR Laser
	4.1	IR LIDAR System
Werner Neupert	9.4	UV-IR Solar Telescope
Stan Ollendorf	2.26	Relativity - Procession Gyroscope
	10.1	IR Chamber/Selector
	12.1	Super-conduction - Cryostat Dewar, He II
	12.2	Long Duration IR Missions - Helium Reliquification
Jonathan Ormes/J. Arens	9.3	Cosmic Ray/Gamma Ray Protective Shell
Harvey Ostrow	2.11	VIS - IR Mapper
David Schaeffer	16.1	Planetary Data Transmission
	16.4	Monitor and Control Data Memory
	16.-	TT&C/Data Processing
	19.4	Software for Experiment Control
Paul E. Schmidt	2.18	Radio - Range & Range Rate Sensor
Stanley Sobieski	2.7	UV Spectrograph, Echelle
	2.19	VIS-UV Photon Detector
	2.20	VIS-UV Polarimeter
	2.21	VIS-UV Electrographic Camera
	2.22	IR-VIS-UV-XUV Filters
Nelson Spenser	5.5	Plasma Data System
	16.1	Transmission Systems - Planetary Probe
Dr. C. E. Velez	19.1 thru 19.4	Software
Oscar Weinstein	1.7	IR Scanner (Thermal Scanner Radiometer)
	2.9 & 2.11	VIS-IR Mapper
	2.12	VIS-IR Spectrometer
John J. Over	10.2	Gravity Gradiometer Temperature Control
Frank J. Capollina/ William Logan, Jr.	5.7	Self Aligning Multipen Electrical Connector
	9.7	Module Resupply Mechanism
	9.8	Spacecraft to Shuttle Docking/Deployment & Retention Mechanism
	9.9	Backup EVA Drives & Tools for Resupply of Modular Spacecraft

APPENDIX A

PERSONNEL CONTACTED

A.3 GODDARD SPACE FLIGHT CENTER, Greenbelt, Maryland 20771 (Continued)

Name	Item No.	Subject/Category
	9.10	Remote Manipulator System End Effector Mechanism - Shuttle to Spacecraft
	9.11	Spacecraft to Tug Docking Mechanism
Thomas T. Wilheit/ Thomas J. Schmugae	2.17	Soil Moisture Sensor
Walter Carrion/ Don Premo	3.1	Visible & IR Laser
Charles MacKentic/ Luther W. Sufer, Jr.	17.1	High Voltage Solar Array

APPENDIX A

PERSONNEL CONTACTED

A.4 LANGLEY RESEARCH CENTER, Langley Station, Hampton, VA 23365

Name	Item No.	Subject/Category
Wendell G. Ayers	2.8 thru 2.11	VIS - IR Mapper
Williard Anderson	2.12 & 2.13	VIS-IR Spectrometer
	2.23	VIS-IR Advanced Atmospheric Sensors Group
D. E. Barthlome	10.4	CO_2 Desorption - Steam Generation, Zero-G
Walter E. Bressette	2.8 thru 2.11	VIS - IR Mapper
	2.12 & 2.13	VIS - IR Spectrometer
	2.23	IR - VIS Advanced Atmospheric Sensors Group
Dr. W. P. Chu	1.8	VIS - IR Optical System for Laser
Gary W. Grew	2.10	VIS - IR Mapper
	2.23	VIS - IR Advanced Atmospheric Sensor Group
Charles Gurtler	2.8 thru 2.11	VIS - IR Mapper
Jack Hall	2.8 thru 2.11	VIS - IR Mapper
	2.12 & 2.13	VIS - IR Spectrometer
	2.23	IR - VIS Advanced Atmospheric Sensors Group
Herbert D. Hendricks	2.14-1	IR Photometer
	2.15	IR Spectrometer, Interferometer
	2.16	IR Pyroelectric Detector, Uncooled
	11.1	Planetary - Structural Mechanism
Robert V. Hess	3.1	VIS & IR Laser
	14.1	Planetary Thruster, Mercury Ion
Edwin T. Kruszewski	9.1	Plasma and Fields - Instrument Boom, 50m
	9.2	Payload and Spacecraft Structure
Don Lawrence	2.10	VIS - IR Mapper
	2.13	VIS - IR Spectrometer
M. P. McCormick	1.8	VIS - IR Optical System for Laser
	2.14-1	IR Photometer
	2.23	IR - VIS Advanced Atmospheric Sensors Group
	3.1	VIS & IR Laser
	14.1	Planetary Thruster, Mercury Ion

APPENDIX A

PERSONNEL CONTACTED

A.4 LANGLEY RESEARCH CENTER, Langley Station, Hampton, VA 23365 (Continued)

Name	Item No.	Subject/Category
R. S. Osborne	2.23	VIS - IR Advanced Atmospheric Sensors Group
James L. Raper	2.8 thru 2.11	VIS - IR Mapper
	2.12 & 2.13	VIS - IR Spectrometer
	2.23	IR - VIS Advanced Atmospheric Sensors Group
H. J. E. Reid, Jr.	15.5	Earth Resources - Star Sensor, Strapped Down, Advanced Gyro
Eugene Sivertson	1.9	Radio - Large Microwave Antenna Arrays
	2.8 thru 2.11	VIS - IR Mapper
Robert B. Spiers, Jr.	2.10	VIS - IR Mapper
	2.23	VIS - IR Advanced Atmospheric Sensor Group
Charles Tynan	10.4	CO_2 Desorption - Steam Generation, Zero G
Willard R. Weaver, Jr.	13.2	Planetary Return - Docking
John W. Wilson	2.15	IR Spectrometer, Interferometer

APPENDIX A

PERSONNEL CONTACTED

A.5 C ORGE C. MARSHALL SPACE FLIGHT CENTER, Marshall Space Flight C ter, Alabama 35812

Nai e	Item No.	Subject/Category
James B. Dozier	8.1	Optical and Plasma - Surface Cleaning
	8.2	IR-IVS-UV-X-RAY Contamination Monitor
	8.3	IR-VIS-UV-X-RAY Contamination Processes Understanding
	8.4	IR-VIS-UV-X-RAY Contamination Avoidance Devices, e.g., Electrets
Garvin Emanuel	1.4	UV-IR-Telescope, Large Optics
Richard B. Hoover	1.2	X-Ray Telescope
Thomas N. Marshall, Jr.	2.15	IR Spectrometer, Interferometer
	11.1	Planetary Structural Mechanism
W. Mordan	9.1	Plasma and Fields - Instrument Boom, 50m
Robert J. Naumann	8.1	Optical and Plasma - Surface Cleaning
	8.2	IR-VIS-UV-X-RAY Contamination Monitor
	8.3	IR-VIS-UV-X-RAY Contamination Processes Understanding
	8.4	IR-VIS-UV-X-RAY Contamination Avoidance Devices, e.g., Electrets
Max Nein	8.1	Optical and Plasma - Surface Cleaning
	8.3	IR-VIS-UV-X-RAY Contamination Avoidance Devices, e.g., Electrets
	15.1	Astronomy Physics - Tracker, Field Monitor and Guide Star Sensors
Charles R. O'Dell	2.19	VIS - UV Photon Detector
	2.22	IR-VIS-UV-XUV Filters
R. A. Potter	1.1	Gamma- Ray Survey Instrument, Large
	1.2	X-Ray Telescope
	2.1	Cosmic Ray Spatial Detector
	9.3	Cosmic Ray/Gamma Ray Protective Shell
	9.4	UV - IR Solar Telescope-Structure
Percy H. Rhodes	5.2	Bio & Organic - Electrophoretic Process
W. Roberts	9.1	Plasma and Fields - Instrument Boom, 50m
Kenneth R. Taylor	5.1	Liquid & Solid - Levitation Unit
W. Thompson	9.1	Plasma and Fields - Instrument Boom, 50m
W. G. Thornton	7.3	Elect.-Mech. Teleoperator Subsystems
	2.18	Range and Range Rate
J. Waite	9.1	Plasma and Fields - Instrument Boom, 50m

APPENDIX A

PERSONNEL CONTACTED

A.5 GEORGE C. MARSHALL SPACE FLIGHT CENTER, Marshall Space Flight Center, Alabama 35812 (Continued)

Name	Item No.	Subject/Category
Paul Schwindt/D. Wasserman	1.4	UV - IR Telescope, Large Optics
	2.19	VIS - UV Photon Detector
	2.21	VIS - UV Electrographic Camera
Dr. Eugene W. Urban	2.26	Relativity - Precession Gyroscope
	10.1	IR Chamber/Selector
	12.1	Super-Conduction Cryostat Dewar, He II
	12.2	Long Duration IR Missions - Helium Reliquification

APPENDIX A

PERSONNEL CONTACTED

A.6 LYNDON B. JOHNSON SPACE CENTER, Houston, Texas 77058

Name	Item No.	Subject/Category
Dr. G. D. Badhwar	2.26	Relativity - Precession Gyroscope
	10.1	IR Chamber/Selector
	12.1	Super-Conduction - Cryostat Dewar, He II
	12.2	Long Duration IR Missions - Helium Reliquification
Dr. G. D. Badhwar/	2.1	Cosmic Ray - Spatial Detector
Mr. Robert L. Golden	18.1	High Energy - Pulse Measurement & Correlation Detection
William J. Burke	2.17	Radio - Soil Moisture Sensor, μw
Karl G. Henize	2.21	VIS-UV Electrographic Camera
	2.22	IR - VIS - UV - XUV Filters
J. L. Lacy	2.1	Cosmic Ray - Spatial Detector
	18.1	High Energy - Pulse Measurement & Correlation Detection
Dr. William B. Lenoir	2.17	Radio - Soil Moisture Sensor, μw
Glen C. Miller	7.3	Elect.-Mech. - Teleoperator Subsystems
Richard A. Moke/ A. Mathews	4.3	Radio - Imaging Radar
Dr. Donald E. Robbins	3.1	VIS & IR Laser
	4.1	IR LIDAR System
Curtiss Mason	2.17	Soil Moisture Sensor

APPENDIX A

PERSONNEL CONTACTED

A.7 JET PROPULSION LABORATORY, 4800 Oak Grove Drive, Pasadena, CA 91103

Name	Item No.	Subject/Category
Dr. Raymond F. Bohling	15.1	Astronomy/Physics - Tracker, Field Monitor and Guide Star Sensors
James Burke	9.5	Planetary - Entry Heat Shield
	10.2	Gravity Gradiometer - Thermal
John C. Beckman	2.15	IR Interferometer Radiometer - Radiation Effects
Walter Brown	1.9	Large Microwave Antennas
Dr. T. Neil Divine	2.15	IR Interferometer Radiometer - Radiation Effects
Dr. Alain L. Fymat	4.2	Nephelometer - Planetary
Charles E. Giffin	5.3	Solids Analysis - Comet Tail
Dr. William A. Mahoney	2.3-1	X-Ray Maximum Sensitivity Detector
	2.4	X-Ray Proportional Counter, Position Sensing
	2.6	X-Ray Converter/Intesifier
	16.5	X-Ray Image Disection
John V. Goldsmith/ Lloyd D. Runkle	17.1 & 17.5	Electric Power
Dr. Ewald Heer	7.3	Tele-operator Subsystem Electro-mech
W. Marco	11.1	Thermal & Pressure Protection for Payload Instruments
Richard H. Parker	2.15	IR Interferometer Radiometer-Radiation Effects
Joseph A. Plamondon	11.1	Thermal & Pressure Protection for Payload Instruments
David H. Rodgers	2.14-2	IR Spectrometer, Interferometer
Dr. Joel G. Smith	16.1	Planetary - Data Transmission
Dr. William H. Spuck	19.1 thru 19.4	Software
Howard Weiner	17.-	Electric Power
Jesse Moore	13.2	Automatic & Remote Docking
	19.1	Software - Rendezvous & Docking

APPENDIX A

PERSONNEL CONTACTED

A.8 AMES RESEARCH CENTER, Moffett Field, California 94305

Name	Item No.	Subject/Category
Kenneth Billman	3.1	VIS & IR Laser
	4.1	IR LIDAR System
Dr. Paul Callahan	7.1	Biological - Life Sciences Organism Holding Units
	7.4	Biological - Surgical
Robert M. Cameron	1.5 & 1.6	IR Telescope, 0.2m & 1.5m, cooled
Duayne Duggan	14.1	Planetary Thruster, Mercury Ion
	14.2	Station Keeping - Thruster, Cesium Bombardment
Terry L. Grant	16.1	Planetary - Data Transmission
	16.4	Monitor and Control - Data Memory
John Kirkpatrick	2.26	Relativity - Precession Gyroscope
	10.1	IR Chamber/Selector
	12.1	Super-Conduction - Cryostat Dewar, He II
	12.2	Long Duration IR Missions - Helium Reliquification
Dr. Dale Lumb	13.1	Planetary - Low Thrust Techniques, SEP
Robert Mah/ William Berry	7.1	Biological - Life Sciences Organism Holding Unit
Craig McCreight	2.26	Relativity - Precession Gyroscope
	10.1	IR Chamber/Selector
	12.1	Super-Conduction - Cryostat Dewar, He II
	12.2	Long Duration IR Missions - Helium Reliquification
Ramsey K. Melugin	1.5	IR Telescope
	1.6	LHe Cooled Telescope
Robert M. Munoz	19.1 thru 19.4	Software
Phil Nachtsheim	9.5	Planetary - Entry Heat Shield
Dr. Jiro Oyama	7.2	Bio-Functional Bioresearch Centrifuge
Dr. Richard Simmonds	7.1	Biological - Life Sciences Organism Holding Units
	7.4	Biological - Surgical
Joel Sperans	18.1	High Energy - Pulse Measurement & Correlation Detection

APPENDIX A

PERSONNEL CONTACTED

A.8 AMES RESEARCH CENTER, Moffett Field, California 94305 (Continued)

Name	Item No.	Subject/Category
Henry Lum	16.—	TT&C - Wide Compression
J. P. Murphy	15.1 & 15.5	Attitude Control
John Parker	5.—	Special Devices
Nick Vojvodich	2.15	IR Spectrometer, Interferometer
	9.5	Planetary - Entry Heat Shield
	11.1	Planetary - Structural Mechanism
	13.2	Planetary Return - Docking
Hubert Vykukal/ James Jones	7.3	Elect.-Mech. Teleoperator Subsystems
Fred Witteborn	1.5 & 1.6	IR Telescope, 0.2m & 1.5m, Cooled
	2.14-1	IR Photometer
	2.14-2	IR Spectrometer, Interferometer
	2.26	Relativity - Precession Gyroscope
	8.	Contamination
	10.1	IR Chamber/Selector
	12.1	Super-Conduction Cryostat Dewar, He II
	12.2	Long Duration IR Missions - Helium Reliquification
Arthur C. Wilbur	17.1	High Voltage Solar Array

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PERSONNEL CONTACTED

A.9 LEWIS RESEARCH CENTER, 21000 Brookpark Rd. Cleveland, Ohio 44135

Name	Item No.	Subject/Category
Bruce A. Banks	14.1	Planetary - Thruster, Mercury Ion
	14.2	Station Keeping - Thruster, Cesium Bombardment
John M. Bozek/	17.1	High Voltage Solar Array
Stan Domitz	17.5	High Energy Density Battery
Dave C. Byers	14.1	Planetary - Thruster, Mercury Ion
	14.2	Station Keeping - Thruster, Cesium Bombardment
Thomas H. Cochran	2.24	G-Jitter Sensor
	2.25	Mass Measurement
James E. Cake	13.1	Planetary - Low Thrust Techniques, SEP
Robert W. Easter/ Marvin Warshay	17.5	Plasma and Earth Applications - High Energy Storage
Bruce E. Leroy	13.1	Planetary - Low Thrust Techniques, SEP
Lyle O. Wright/ Stan Domitz	17.1	High Voltage Solar Array
Edward Miller/ Norbert Stankiewite/ Robert Alerevich	5.4	High power Transmitter

A.10 WALLOPS FLIGHT CENTER, Wallops Island, Virginia 23337

Name	Item No.	Subject/Category
J. T. McGoodan	4.4	Radio - Altimeter, Pulsed K-Band

APPENDIX B

MANUFACTURER/LABORATORY AND UNIVERSITY PARTICIPANTS

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APPENDIX B

MANUFACTURER/LABORATORY AND UNIVERSITY PARTICIPANTS

B.1 CONTRIBUTING MANUFACTURERS/LABORATORIES

Organization & Participant	Item No.	Subject/Category
A. D. Little, Inc. 25 Acorn Park Cambridge, Mass. 02140 R. W. Breckenridge	2.26 12.1 12.2	Relativity-Precession Gyroscope Super-conduction-Cryostat Dewar, HeII Long Duration IR Missions - Helium Reliquification
Barnes Engineering Co. 30 Commerce Road Stamford, Connecticut 06904 R. Martin	1.8	VIS-IR Optical System for Laser
Barnes Engineering Company 30 Commerce Road Stamford, Connecticut 06904 S. Weiner	2.16	IR Pyroelectric Detector, Uncooled
Battelle Columbus Lab. 505 King Ave. Columbus, Ohio 13201 D. J. Hammon	2.15	IR Spectrometer, Interferometer
Bell Aerospace P. O. Box 1 Buffalo, New York 14205 Ernest H. Metzger (I-85)	6.1	Accelerometer Sensitivity
Block Engineering 19 Blackstone St. Cambridge, Mass. 02173 Geert Wijntjes	2.7 2.13 2.14-1 2.14-2	UV Echelle Spectrograph VIS-IR Spectrometer IR Photometer IR Spectrometer, Interferometer
Boeing Company Box 3707 Seattle, Washington 98124 R. B. Gillette	8.1 8.3	Optical and Plasma-Surface Cleaning IR-VIS-UV-X-RAY Contamination Processes Understanding

APPENDIX B

B.1 CONTRIBUTING MANUFACTURERS/LABORATORIES (Continued)

Organization & Participant	Item No.	Subject/Category
Brown Engineering Company Research Park Huntsville, Alabama 35807 Dr. Neil E. Chatterton	8.4	IR-VIS-UV-X-RAY Contamination Avoidance Devices, e.g., Electrets
C. S. Draper Labs 75 Cambridge Parkway Cambridge, Mass. 02142 T. N. Edelbaum/J. J. Deyst, Jr.	13.1	Planetary - Low Thrust Techniques SEP
Control Data Corporation Hawthorne Division 2815 West El Segundo Blvd. Hawthorne, California 90250 T. C. Farrel, Jr.	16.4	Monitor and Control-Data Memory
Faraday Labs P.O. Box 2308 La Jolla, California 92037 Dan McKeown	8.1 8.2	Cleaning of Optical Surfaces IR-VIS-UV-X-RAY Contamination Monitor
The Garrett Corp. AiResearch Mfg. Co. of Calif. Mail Station T-25 2525 W. 190th Street Torrance, California 90509 R. Hunt	10.4 12.1 12.2	CO_2 Decomposition - Steam Generation in Zero-g Super-Conduction-Cryostat Dewar, He II Long Duration IR Missions - Helium Reliquification
General Dynamics Data Systems Services P.O. Box 80847 San Diego, California 92138 C. H. Gutzler	19.1 thru 19.4	Software

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B.1 CONTRIBUTING MANUFACTURERS/LABORATORIES (Continued)

Organization & Participant	Item No.	Subject/Category
General Electric Co. Corporate Research & Dev. Building 37, Room 559 Schenectady, N.Y. 12345 R. E. Anderson	2.18	Radio-Range & Range Rate Sensor
General Electric Co. Space Division P.O. Box 8555 Philadelphia, PA 19101 Dr. T. R. Rietof/ Dr. H. M. Bortner	2.23	IR-VIS Advanced Atmospheric Sensors Group
General Electric Company Bldg. 100 Room M-9555 P.O. Box 8555 Philadelphia, PA 19101 Dr. R. T. Frost/ Dr. Robert Soberman	5.1 2.24 2.25	Liquid & Solid - Levitation Unit Gravity Measurement, Low Mass and High Accuracy Mass Measurement, Low Mass and High Accuracy
General Electric Space Division P.O. Box 8555 Philadelphia, PA 19101 Dr. A. T. Tweedie	8.2	IR-VIS-UV-X-RAY Contamination Monitor
Honeywell Radiation Center Mail Zone 20 2 Forbes Road Lexington, Mass 02173 H. R. Tavares/Carl R. Bohne	2.9 2.14-2	VIS-IR Mapper (Tavares) IR Spectrometer, Interferometer (Bohne)
Honeywell Radiation Center 2 Forbes Road Lexington, Mass 02173 R. A. Rotolante	2.15	IR Spectrometer, Interferometer

APPENDIX B

B.1 CONTRIBUTING MANUFACTURERS/LABORATORIES (Continued)

Organization & Participant	Item No.	Subject/Category
Honeywell Radiation Center 2 Forbes Road Lexington, Mass 02173 B. Stanton	15.1	Astronomy Physics-Tracker, Field Monitor and Guide Star Sensors
Hughes Aircraft Company Centinela & Teale Streets Culver City, California 90230 J. N. Brown	1.5	IR Telescope, 0.2m & 1.5m, cooled
Hughes Aircraft Co. Laser Communication Dept. P.O. Box 92919 Los Angeles, California 90009 F. E. Goodwin	3.1	VIS & IR Laser
Hughes Research Laboratory 3011 Malibu Canyon Road Malibu, California 90265 Dr. R. L. Forward	10.2 18.5	Gradiometer Passive Temperature Control Gravity Analog/Digital Filtering
Hughes Research Laboratory Ion Physics Dept. 3011 Malibu Canyon Road Malibu, California 90265 J. H. Molitor	14.1 14.2	Planetary - Thruster Mercury Ion Station Keeping-Thruster, Cesium
Hughes Aircraft Co. Space & Communications Group El Segundo, California 90245 B. Klestadt	15.5	Earth Resource-Star Sensor, Strapped Down, Advanced Gyro

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B.1 CONTRIBUTING MANUFACTURERS/LABORATORIES (Continued)

Organization & Participant	Item No.	Subject/Category
IBM Federal Systems Div 10215 Fernwood Rd. Bethesda, Md. 20034 R. J. Kirchoff	19.1 thru 19.4	Software
IBM Federal Systems Div 10215 Fernwood Rd. Bethesda, Md. 20034 W. A. Bohan	16.4	Monitor & Control - Data Memory
Intermetrics Inc. 701 Concord Ave. Cambridge, Mass 02128 W. Zimmerman	19.1 thru 19.4	Software
Itek Corporation Optical Systems Division 10 Maguire Road Lexington, Mass 02173 Tom Vogt	1.2 1.8 2.8 9.4	X-Ray Telescope VIS-IR Optical System for Laser VIS-IR Mapper UV-IR Solar Telescope
Logicon P.O. Box 471 San Pedro, California 90733 Robert E. Brooks	19.1 thru 19.4	Software
Martin Marietta Corp. Denver Division P. O. Box 179 Denver, Colorado 80201 W. T. Scofield	13.2	Planetary Return-Docking
Martin Marietta Corp. P.O. Box 179 Denver, Colorado F. A. Smith	16.1	Planetary - Data Transmission

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B.1 CONTRIBUTING MANUFACTURERS/LABORATORIES (Continued)

Organization & Participant	Item No.	Subject/Category
Martin Marietta Denver Division Box 179 Denver, Colorado 80201 R. D. Vaage	19.1 thru 19.4	Software
Motorola Inc. Government Electronics Div. 8201 E. McDowell Road Scottsdale, Arizone 85251 J. E. Kirch	5.4	Improved Life and High Power RF Amplifiers
Naval Research Laboratory Washington, D.C. 20375 George Carruthers	2.21	VIS-UV Electrographic Camera
Philco-Ford Aeronutronic Division Ford Road Newport Beach, California 92663 R. R. Auelmann/R. R. Sernka	9.4	UV-IR Solar Telescope Metering Structure
RCA Advanced Technology Labs Bldg. 10-8 Front & Cooper Sts. Camden, N.J. 08102 P. E. Wright	2.26 12.1 12.2 16.4	Relativity-Precession Gyroscope Super-Conduction-Cryostat Dewar, He II Long Duration IR Missions - Helium Reliquification Charge Coupled Devices for Data Storage
Rockwell International Autonetics Group 3370 Miraloma Ave. P.O. Box 4192 Anaheim, California 92803 E. T. Brown	16.4	Monitor and Control Data Memory

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B.1 CONTRIBUTING MANUFACTURERS/LABORATORIES (Continued)

Organization & Participant	Item No.	Subject/Category
Santa Barbara Research Center 75 Coronomar Drive Goleta, California 93017 R. F. Hummer	2.8 thru 2.11 2.12 2.14-2	VIS-IR Mapper VIS-IR Spectrometer IR Spectrometer, Interferometer
System Development Corp. 2500 Colorado Avenue Santa Monica, California 90406 R. D. Knight	19.1 thru 19.4	Software
TRW Systems Group Bldg. R1 Room 1196 One Space Park Redondo Beach, California 90278 J. F. Friichtenicht	5.3	Lower density measurement of solid particles
Westinghouse Electric Corp. Systems Development Div. P.O. Box 746 - M.S. 433 Baltimore, Md. 21203 James F. Pitts	1.7 2.9 2.18	IR Scanner (Thermal Scanner Radiometer) VIS-IR Mapper Radio - Range & Range Rate Sensor
Westinghouse Electric Co. Defense Space Center P.O. Box 746 Baltimore, Md. 21203 Fred Schaff	2.19	VIS-UV Photon Detector
Westinghouse Electric Corp. Aerospace & Electronics Sys Div P. O. Box 746 Baltimore, Md 21203 R. C. Fox	1.9 4.3	Radio-Large Microwave Antenna Arrays Radio-Imaging Radar

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B.1 CONTRIBUTING MANUFACTURERS/LABORATORIES (Continued)

Organization & Participant	Item No.	Subject/Category
Westinghouse Electric Corp. Astronuclear Laboratory Silicon Carbide Technology P.O. Box 10864 Pittsburgh, PA 15236 Dr. R. B. Campbell	11.1	Planetary - Structural Mechanism
Xerox Corporation Electro-Optical Systems Instrument & Propulsion Dept. 300 N. Halstead Street Pasadena, California 91107 Dr. R. M. Worlock	14.1 14.2	Planetary - Thruster, Mercury Ion Station Keeping - Thruster, Cesium Bombardment

B.2 CONTRIBUTING UNIVERSITIES

Organization & Participant	Item No.	Subject/Category
Center for Radar Astronomy Durad 21 Stanford University Stanford, California 94305 Dr. Von Eshleman	5.5	Plasma Data System Reduce effects of boom mounted insitu data system on plasma measurements
Space Technology Center University of Kansas Lawrence, Kansas 66044 Dr. Fawwaz T. Ulaby	2.17	Radio - Soil Moisture Sensor, μw
Physics Department Stanford University Stanford, California 94305 Dr. John A. Lipa	12.1 2.26	Super-Conduction Cryostat Dewar, He II Relativity - Precession Gyroscope

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B.2 CONTRIBUTING UNIVERSITIES (Continued)

Organization & Participant	Item No.	Subject/Category
University of California	2.2	X-Ray Transmission Grating
Space Science Laboratory	2.3-1	X-Ray Maximum Sensitivity Detector
Berkeley, California 94720	2.3.2	X-Ray Polarimeter
Dr. Mike Lampton	2.4 & 2.5	X-Ray Proportional Counter, Position Sensing
	2.6	X-Ray Converter/Intensifier
	19.4	Software
University of California	2.1	Cosmic Ray Spatial Detector
Lawrence Radiation Laboratory Berkeley, California 94720	9.3	Cosmic Ray/Gamma Ray Protective Shell
Dr. Andrew Buffington	18.1	High Energy Pulse Measurement and Correlation Detection
	18.2	Cryogenic Superconducting Magnet Control
Center for Astrophysics	1.2	X-Ray Telescope
Smithsonian Astrophysical	2.2	X-Ray Transmission Grating
Observatory	2.3.1	X-Ray Maximum Sensitivity Detector
High Energy Astrophysical	2.3.2	X-Ray Polarimeter
Division	2.4	X-Ray Proportional Counter, Position Sensing
60 Garden Street		
Cambridge, Mass 02138	2.5	X-Ray Proportional Counter, Position Sensing
Marvin L. Lipshutz	2.6	X-Ray Converter/Intensified
Program Manager, HEAO-B	9.6	X-Ray Instrument Mount/Selector